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ABSTRACT

A future-oriented report on secondary school science facilities is presented in this book by the National Science Teachers Association to provide assistance in school design. Examplar facilities of more than 140 observed schools are analyzed in connection with the social influences on science education and the evolving patterns in technology, instructional programs, and student-staff relations. Detailed descriptions are made in terms of instructional space, construction requirements, and management of instructional materials. The trend toward flexibility is emphasized in dealing with aspects of acoustics, internal walls, visual considerations, room furnishings, student groupings, utilities, and safety. Individual learner's needs are described as a major criterion, and consultations with architects are taken into account. The findings are summarized into: 1) Location of science facilities, 2) Alternative arrangement of facilities, 3) Laboratory furnishings, 4) Supply logistics, 5) Technological support, 6) Human environment, and 7) Community resource utilization. Besides illustrations, an annotated bibliography, a nomination form, and tables of environmental criteria are included in the appendices. The work of the Study Team was financially supported by the National Science Foundation. (CC)

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Evolving Patterns in Facilities and Programs

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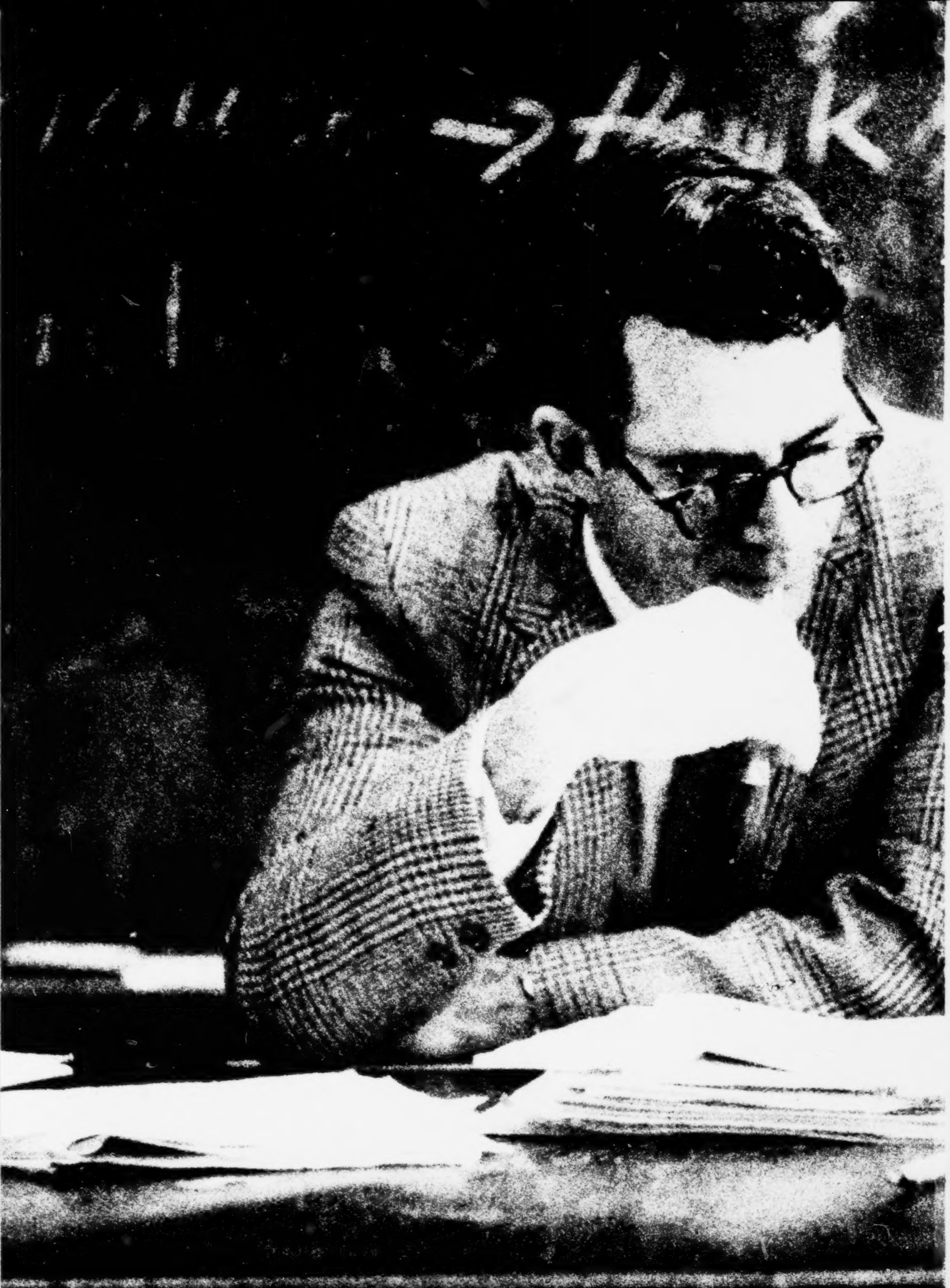

Facilities for Secondary School Science Teaching

Evolving Patterns in Facilities and Programs

ED 077656

Report of a study conducted by the
National Science Teachers Association
with financial support from the
National Science Foundation

Joseph D. Novak
Project Director and Author

National Science Teachers Association
Washington, D.C.

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Foreword

To provide assistance in the design of secondary school science facilities, the National Science Teachers Association in 1954 published its first book on facilities, *School Facilities for Science Instruction*. This book was modified and updated in 1961. Although subsequently the Association published several related pamphlets, it became evident by the end of the decade that a new and substantially different report was needed on secondary school science facilities. Moreover, the rapid changes occurring in schools and the likely prospect that innovations in programs and curricula will increase during the 70s indicated a need for a report based on a study of trends in the design and use of facilities.

New secondary school science curricula were published in the late 1950s and early 1960s. Many were the result of curriculum development projects supported by the National Science Foundation. Science teaching had taken on new importance with the launching of the Soviet Sputnik in 1957 and the accelerated space programs in the 1960s. By 1970, however, science enrollments and national emphasis on "big science" had begun to decline. Simultaneously, open schools and other new administrative concepts were beginning to appear. A new emphasis on preservation of environmental quality, the recognition of new social concerns, and a revised set of educational priorities were also becoming evident. Alternative life styles of college students began to spread to secondary schools, with an emerging demand for attention to **individual** needs. [1] Clearly, a new appraisal of the rationale for and of the purposes to be served by secondary school science facilities was needed.

A tentative proposal for support of a science facilities study was submitted to the National Science Foundation (NSF) in the summer of 1969, following informal discussions with NSF personnel. The proposed project evolved through these discussions, with the emphasis placed on the study of **exemplary** facilities rather than on a survey of representative existing facilities. Furthermore, it became evident that the study should attempt to identify emerging trends or patterns and that the report should be future-oriented. In April 1970, NSF approved a grant to NSTA for a project to be carried out by a study team under the direction of Joseph D. Novak of Cornell University.

The Association is pleased now to make this report available to teachers, school administrators, architects, and others who help to plan the design of physical facilities as well as the programs of science in our schools.

We recognize that not all facilities could be included in the study, and, quite possibly, some promising innovations may have been overlooked. Nevertheless, we believe that the study team has assembled a representative report of both facilities and innovations in science programs. NSTA will welcome suggestions and comments on this report, for these will prove useful in future publications relating to facilities and programs in science.

Robert H. Carleton
Executive Secretary
National Science Teachers Association

Preface

Education in Secondary Schools was supported by a grant from the National Science Foundation. The original plan of the study was to identify and study **exemplary** secondary school science facilities. It was hypothesized that a careful study of examples of outstanding facilities, together with inquiry about the philosophy and rationale of the instructional program, could give direction to new and improved plans for school designs for science. As the study progressed, we found that this view was too narrow and that programs must be considered along with facilities.

To organize the study, the project director, with counsel from NSTA officers and staff, selected a study team of six members, one member for each of six regions of the United States. Each team member participated in establishing criteria for selection of sites to be studied, visited selected facilities, provided his interpretation of them, and gave counsel to the project director as the study progressed.

The study team established two primary criteria for facilities to qualify as exemplary: (1) the facility must provide for easy modification or **flexibility,** and (2) the facility must allow for increasing **individualization** of instruction. The criteria were well chosen, for we found in school after school that teachers were striving to redeploy their space and equipment to allow for more individualized programs in science.

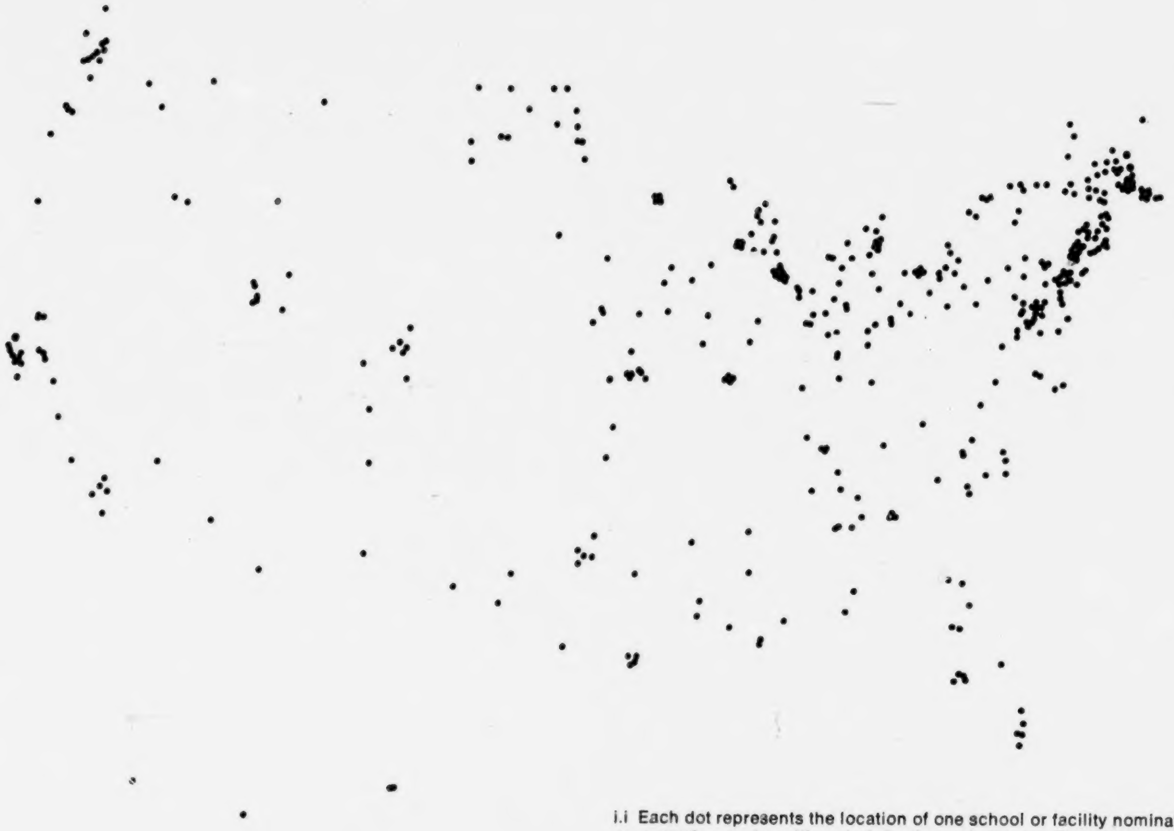
The search for the exemplary facilities began in late spring 1970 when a one-page form requesting nominations of suggested exemplary science facilities was mailed to state science supervisors, to science supervisors listed in the NSTA Registry of Science Teaching Personnel, and to other selected individuals. At a planning meeting in Washington in June the study team reviewed early returns of nomination forms. It was evident from these returns that nominations in the largest group were for facilities that were conventional in design and program practices; another group of nominations could not be evaluated with the information provided; and a third group showed promise both in terms of serving present program needs and in terms of potential flexibility in use.

A revised nomination form was prepared by the team for subsequent distribution. The new form listed 21 criteria to be considered by the nominator (see Appendix). It stressed that we were seeking nominations of **exemplary** facilities with "flexibility to meet present and future educational objectives." Copies of the new form were mailed to several groups in science teaching, professional leadership, commercial exhibitors at NSTA meetings, members of the National Association for Research in Science Teaching, and other individuals and groups. Nominations were also solicited through the *NSTA News-Bulletin* and the newsletter of the National Association of Biology Teachers. Announcements of the study and requests for nominations were sent to numerous other organizations. In all, nearly one thousand nominations were returned.

During the summer and early fall of 1970, study team members visited more than 60 selected facilities. A second planning meeting was held in Washington in October 1970. Each study team member described the facilities and programs he or she had studied and gave an evaluation of these according to the criteria established earlier. This second meeting found team members largely in agreement on the kinds of facilities and programs that appeared to be forward-looking. This concurrence of views increased as school visits continued. By the time of the team's third meeting in Washington in March of 1971, we found ourselves almost embarrassingly in agreement.

Subsequent to the second planning meeting, the project director and the project associate, K. Michael Hibbard, visited those facilities selected as most outstanding by the study team members. None of these facilities was outstanding by every criterion we used, but representative sites that were exemplary in several ways were selected. These follow-up visits of one or two days at a given site were usually conducted as two-man teams with Novak and/or Hibbard accompanied by a study team member. These visits were impressive in the degree of agreement in evaluations made by the visiting team.

Preface



i.i Each dot represents the location of one school or facility nominated as exemplary and meriting study by the project team. The pattern of nominations roughly approximates the population distribution.

To recapitulate: Selection and evaluation were done by the project staff with three levels of screening. Nomination forms were reviewed; preliminary site visits were conducted by a study team member; follow-up visits to selected sites, based on prior evaluations, were done jointly by study team members and Novak or Hibbard. More than 140 selected schools and facilities were included in this study. All of the "better" schools visited were striving for modifications in the facilities and/or programs. Furthermore, the direction of these hoped-for changes showed striking similarity from school to school. Figure **i.i** shows the locations of the schools nominated.

This report is based on the project staff reports and observations from site visitations to facilities. It also draws on library references, counsel from architects, and communication with various industry representatives. Figure **i.ii** shows the location of facilities visited.

As the study team accumulated examples and studied notes from conversations with teachers and supervisors, we identified four main areas of concern in the schools visited. These were facilities, technology, the instructional program, and student-staff relationships. Moreover, there was an evident direction to changes teachers were seeking in each of these areas. We have, therefore, described four distinct "patterns" in secondary school science and the apparent directions in which schools are moving within these patterns.

Part 1 of this report presents the four "evolving patterns" and their relation to facilities. Part 2 gives details and descriptions of observed science facilities. The appendix includes lists of facilities visited as well as some construction details. An annotated bibliography provides references pertinent to the discussion of the evolving patterns, articles on specific design problems, and selected references describing support facilities, such as nature centers and planetariums.

Although most of the facilities studied were in new or recently constructed buildings, we believe this report should have value for teachers and administrators with any type of facility. In fact, it was commonly observed that teachers in new as well as in older facilities were trying to modify their programs and facility arrangements in directions suggested in this report and to make better use of existing facilities.

i.ii Each dot represents the location of one school or other science facility visited by one or more study team members.

A major criterion employed in selection of sites to be visited was the extent to which the facility afforded opportunity to **individualize** instruction. Since most educators are searching for ways to move in the direction of greater focus on the individual learner's needs, this report should find its way into many curriculum libraries.

Study team members were typically bombarded with questions from teachers and administrators during their visits. We were impressed with the hospitality shown and with the obvious sincerity and earnestness of teachers and administrators to obtain suggestions on how to improve their use of existing facilities.

As our team began this study we found areas of consensus and areas where some members held differing views. This heterogeneity was useful, for it caused us to observe more carefully certain aspects of facilities and program. We found that as the school visits continued, we were increasingly in agreement as to the type of facility that held most promise for given science programs or emerging programs. But the most emphatic consensus emerged in an area that none of us would have predicted — the most promising facilities and programs were found in those schools (old or new) where the principal concern was with children as developing human beings. We see great promise in the growing concern for humanism, for placing importance on acquiring knowledge not as an end in itself but as a means to help young people understand their environment better and to grow in human sensitivity as well. To this end, we dedicate this report.

Joseph D. Novak
Ithaca, New York
August 1972

Acknowledgments

This study represents the cooperative input of literally hundreds of individual efforts.

First acknowledgment and gratitude must go to the National Science Foundation which generously provided support for the study. Several NSF staff members also aided the work through their comments and suggestions.

Interested persons submitted nomination forms and indicated their recommendations for attributes of exemplary facilities. The energy and cooperation of study team members made it possible to visit twice as many selected facilities as was originally planned. And on every visit, teachers and administrators offered exceptional hospitality and cooperation; many staff members of the schools visited provided other forms of subsequent assistance. Donald Ring, now with the Wheeling, Illinois, Public Schools, aided in several school visitations.

Counsel on architectural features was generously provided by Earl Flansberg of Flansberg & Associates, Cambridge, Massachusetts, and Robert Matyas of Cornell University.

We also enjoyed useful counsel from our board of consultants. Their comments and support were encouraging as we moved to completion of the study.

The project director was ably assisted by Michael Hibbard, project associate, and by several colleagues at Cornell University, especially Paula Horton, who did most of the correspondence and typing; Janice Cook, Corine Norberg, and Carol Scheele, who gave technical assistance; and Nancy Ridenour, who assisted in preparation of the manuscript.

The staff of NSTA, particularly Robert H. Carleton and Mary E. Hawkins, contributed counsel and ideas as well as administrative and editorial assistance.

To all of these and to many others the director and study team owe much that is of value in this report.

Joseph D. Novak
Ithaca, New York
August 1972

Interpretations of Secondary School Science Programs

Part

Chapter 1

Societal Influences on Science Education Programs

No serious study today, on any topic, can escape societal influences. Restlessness, uncertainty, and change, ever more profoundly pervasive throughout society, leave nothing untouched. The accelerating rate of change sweeps away the old and compounds the impact of the new — shifting values and intensifying social problems. Many currently popular writers attribute our neuroses to this acceleration. Aptly calling this phenomenon *Future Shock,* Alvin Toffler, for example, develops the thesis that the increasing rate of change makes it impossible for many individuals to accommodate to the new conditions. [2] The result is that they suffer from "future shock." This effect derives from an inability of the individual to adjust his behavior patterns to those patterns more compatible with the behaviors required for success or for coping with altered circumstances. Neither science nor education can afford to ignore the effects of change and the risks of future shock.

Turning to another area: the traditional American ethic of hard work and plain living. What is occurring with respect to these values? Do they still mesh with our educational programs? To a large extent, our affluent society has already disposed of plain living. Now young people in increasing numbers are questioning the value of education for job opportunities that lead only to greater monetary reward and the possibility of more material possessions at the expense of meaningful human relations. Possibly, five or ten years from now youth may again seek material success as other generations did after World War II. Whatever the pattern may be, the way in which young people move to achieve their personal and economic goals is almost certain to be substantially different from that of their parents. Although we have already moved from an agrarian to a highly urbanized society, in which service employment predominates over employment in production, we are likely to see further shifts in the employment roles of people in the next few decades.

All such social changes have an important bearing on school instruction and particularly upon science instruction. Building from the value structure of the adult in post World War II America, science curricula moved toward intensive academic training to produce more and better engineers, scientists, and technicians. The product of this training put man on the moon, refined the computer, and produced transistor radios, tape recorders, and a host of other new electronic gadgetry. But how did it contribute to the quality of life? To the parent whose teen-age child blasts rock music through the house with his 200-watt stereo system, new technology may mean new tyranny. Those parents who have learned to enjoy the new music as another form of human expression may be less troubled, but they cannot dismiss the realization that in important ways their children value some things that are new and unfamiliar to them.

What significance do these social changes have for school science facilities? How do we proceed to discern the effects of social changes or the direction of change on the school program and facilities? Have changes in the postwar value structure for science brought concomitant modifications in school facilities? Is there a trend away from hard-core science programs to programs through which students perceive the role of science in regard to what is going on in society? Is society running away from us, or can the schools still have an influence on the prevention of "future shock"? These were inescapable questions in our study of school facilities for science.

Societal Influences on Science Education Programs

By and large, the educational product of our schools is molded by the value orientations of the society, for schools reflect the values of the society that supports them. Societal values inevitably have subtle but profound effects on school curriculum and instructional practices. To illustrate this relationship, we refer to a curriculum-instruction model, proposed by Mauritz Johnson, Jr., [3] and diagrammed in Figure **1**. As the figure indicates, societal values play an important role in the selection and ordering of knowledge to be taught in schools. They also impinge on determination of the teaching practices to be encouraged or discouraged. The end product of this system is the educated young adult who will play his role in setting values for the education of the next generation. But where are new values introduced, new societal goals set?

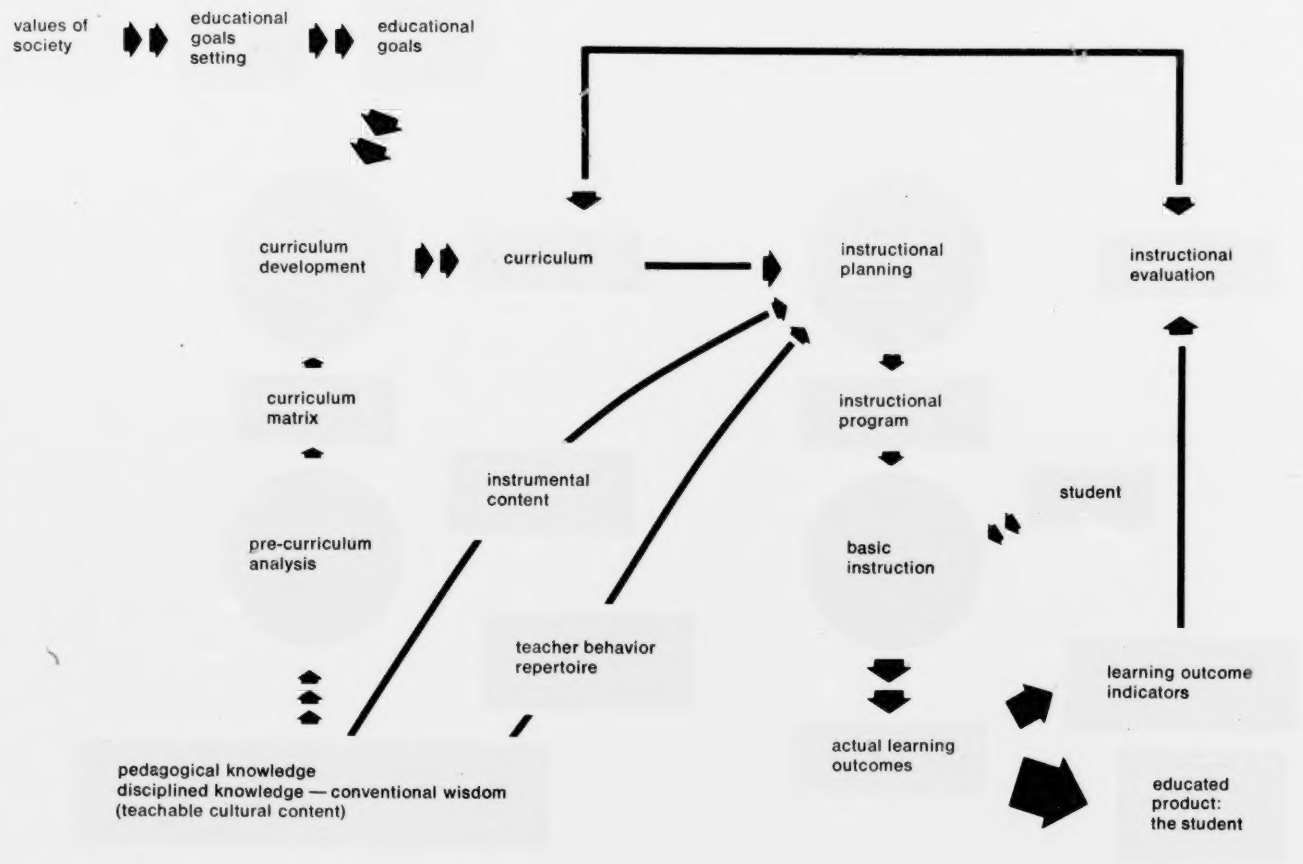
This model assumes that the values of society are generated outside of the curriculum-instruction model. Even attitudes, such as those toward the miniskirt, long hair on males, sex in motion pictures have been formed by young and old almost independently of schools. Nor does all education take place in schools. Much of what children and adults have learned about space travel, as only one example, has been learned through the mass media. Postman and Weingartner comment on the discrepancy between societal changes and the role of schools in preparing students to live in society:

> "It is the thesis of this book that change — constant, accelerating, ubiquitous — is the most striking characteristic of the world we live in and that our educational system has not yet recognized this fact. We maintain further that the abilities and attitudes required to deal adequately with change are those of the highest priority and that it is not beyond our ingenuity to design school environments which can help young people to master concepts necessary to survival in a rapidly changing world." [4, pp. xiii-xiv]

To design school environments which help young people learn not only to survive but also to mature in a self-satisfying way in a rapidly changing world — this is the challenge to which this report addresses itself. We began this study with the recognition, based on our past experience, that it was essential for school science facilities to provide flexibility in learning environments and to offer potential for individual and small-group study. As we concluded the study, we recognized that our early concepts were too neutral and that we must take definite positions on many current practices as well as on facilities. We have categorized these practices in four patterns, each containing its own hierarchy of practices.

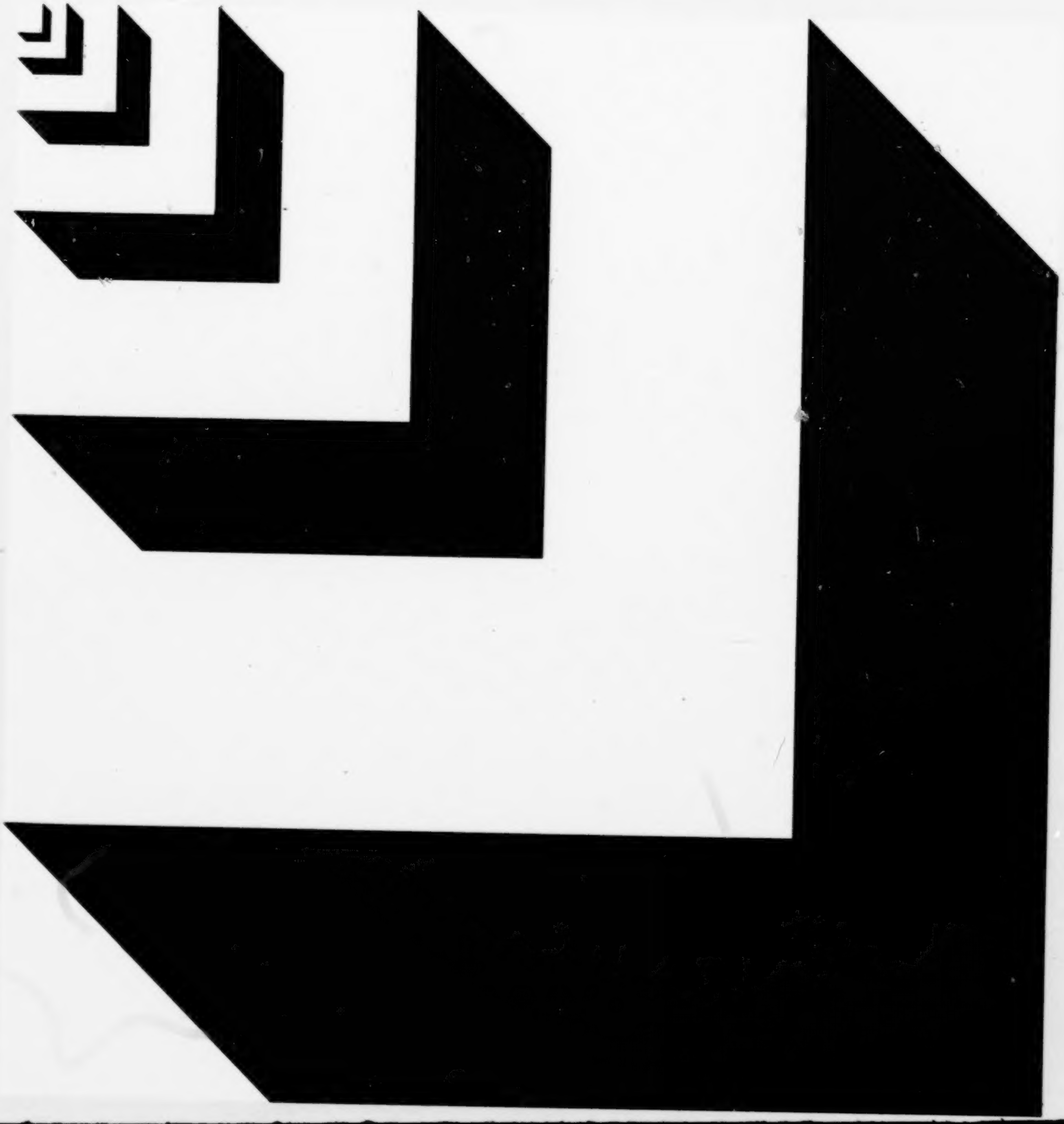
In Part 2 we will deal more specifically with facilities. For example, we cannot recommend the plan of any new science facility in which laboratory benches are designed for a specific subject area and are anchored to the floor in rows, nor even one in which storage facilities are planned for lockstep progression through a fixed series of laboratory experiments.

We suggest that readers of this report study carefully these evolving patterns described in the next chapter. We believe that the "upper level" descriptions provided in the patterns described for facilities, technology, program, and student-staff relations represent reasonable near-term goals for science education. We see these goals as compatible with changes occurring in other areas of the school curriculum. We challenge our readers to discuss and debate these recommendations with their colleagues.


values of society
educational goals setting
educational goals
curriculum development
curriculum
instructional planning
instructional evaluation
curriculum matrix
instructional program
instrumental content
student
pre-curriculum analysis
basic instruction
teacher behavior repertoire
learning outcome indicators
actual learning outcomes
pedagogical knowledge
disciplined knowledge — conventional wisdom
(teachable cultural content)
educated product: the student

1.1 Model for development of curriculum and instruction showing various activities and "products" involved. Societal values influence the design of curriculum and instruction, which in turn affects the kind of educated student produced. During periods of rapid social change, all elements shown in this model must undergo corresponding changes. (after Johnson, 1967, 1970 [3])

Chapter 2



Evolving Patterns in Secondary School Science

As described earlier, the study began with nationwide nominations of facilities thought to have exemplary features. The study team members visited and studied many of these facilities and talked with school personnel about their present and long-term objectives.

Gradually, as the study progressed, the study team reached a consensus with regard to the better designs for space, furniture, and technology and with regard to programs that showed promise. The views derived in part from what we had observed and in part from the discussions with teachers as they described the many specific changes they were seeking.

From our efforts to classify the wished-for changes and the types of facilities and programs observed, the following four general patterns emerged:

1. **Changes in facilities** — from separate lecture-discussion and laboratory rooms, usually for a single subject, to open areas for a wide variety of learning activities.

2. **Increased use of technology** — from blackboard and overhead projectors and/or closed-circuit television for group teaching to self-paced study guides with 8mm loop films, filmstrip viewers, and carrel units equipped with a variety of aids for individualized study.

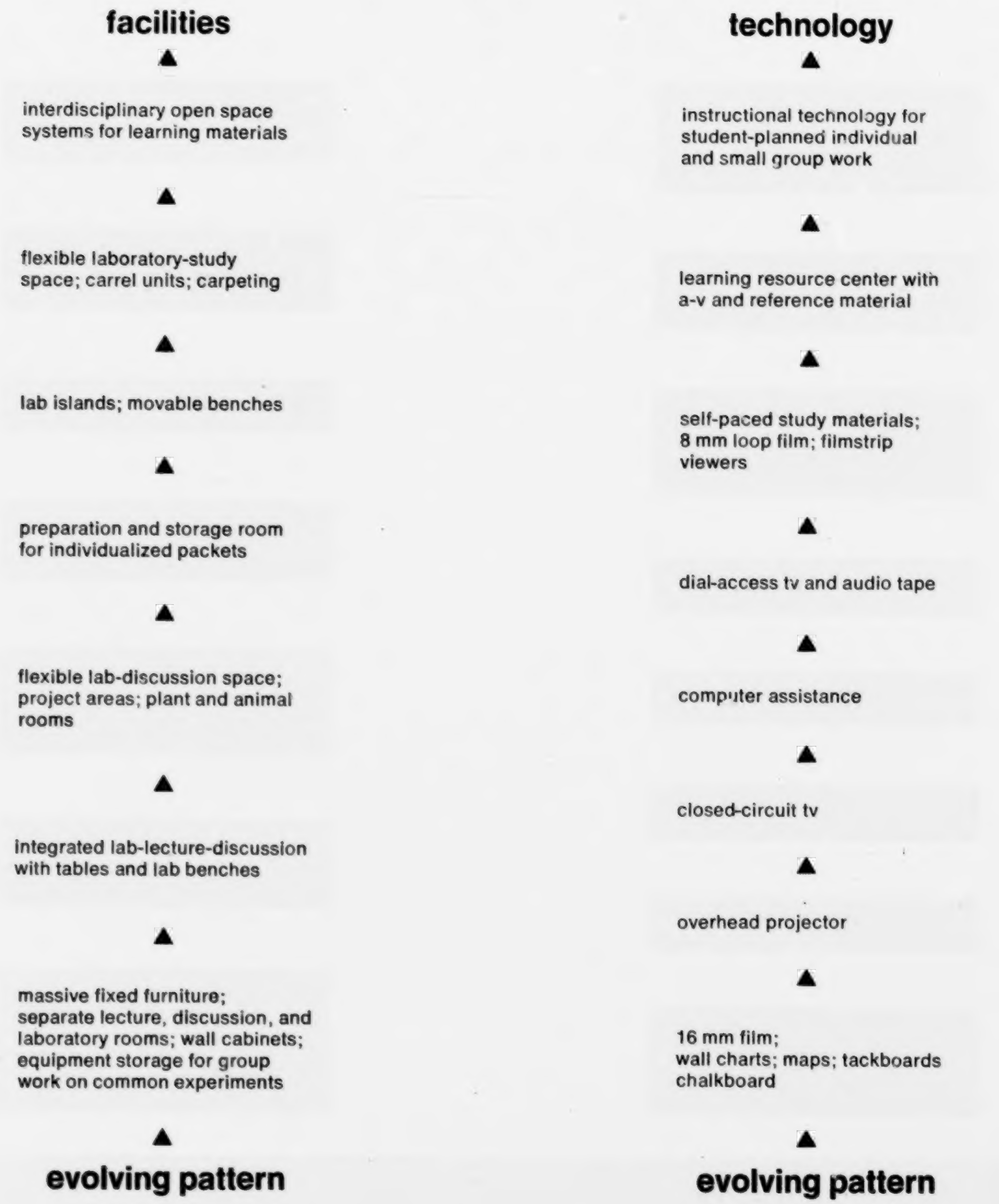
3. **Program modifications** — from single discipline, group-paced, norm-grading, lecture-discussion-laboratory to individually paced, criterion-referenced grading, integrated science with heterogeneous age groups, and some coordination with other studies and career orientation.

4. **Varied student-staff relations** — from teacher-dominated determination of curriculum and performance standards toward student-staff planned achievement goals, alternate curriculum paths, and use of resource personnel with various responsibilities.

Evolving Patterns in Facilities and Programs

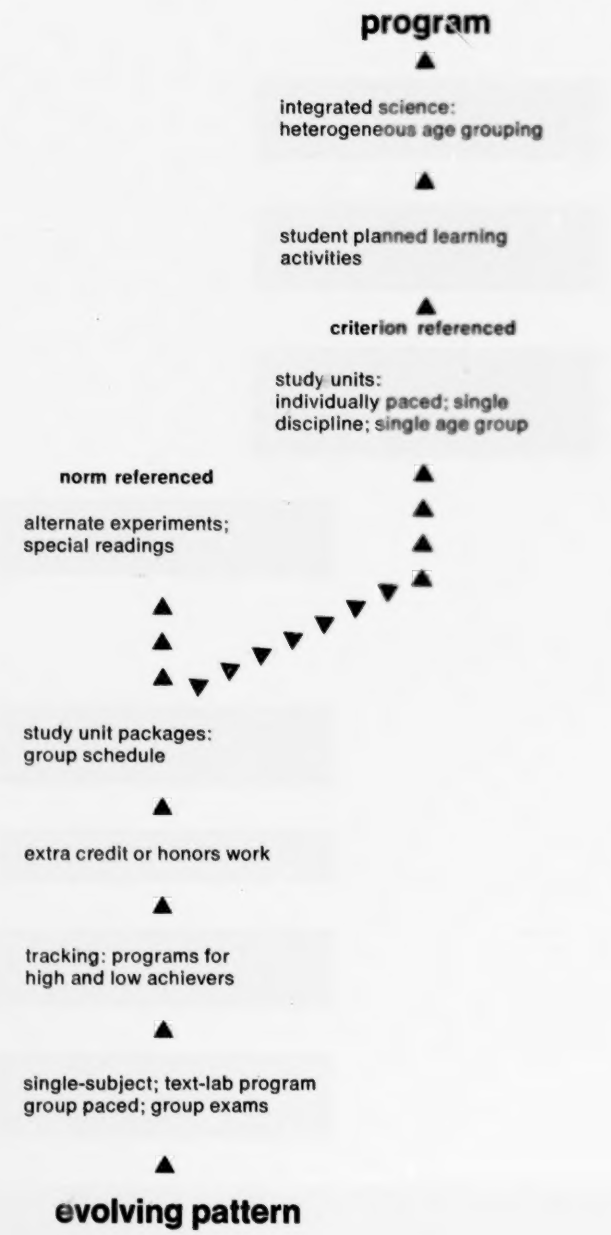
Figure 2.1 diagrams these four evolving patterns. The monotonously similar and traditional equipment and activities observed in the majority of schools visited are noted in the lowest blocks on the arrows. The more promising practices are entered at the top of the patterns

We do not wish to suggest that every school should proceed through each of the stages shown; in fact, the purpose of this report is to assist schools in moving to new combinations of facilities and program without repeating all of the evolutionary stages identified in our observations. Also, as in biological evolution, some facility or program structures continue to be of value even when more advanced stages are reached. For instance, chalkboards will always be useful teaching aids, and books of many types will always be important in science programs.


facilities
interdisciplinary open space systems for learning materials
flexible laboratory-study space; carrel units; carpeting
lab islands; movable benches
preparation and storage room for individualized packets
flexible lab-discussion space; project areas; plant and animal rooms
integrated lab-lecture-discussion with tables and lab benches
massive fixed furniture; separate lecture, discussion, and laboratory rooms; wall cabinets; equipment storage for group work on common experiments
evolving pattern
technology
instructional technology for student-planned individual and small group work
learning resource center with a-v and reference material
self-paced study materials; 8 mm loop film; filmstrip viewers
dial-access tv and audio tape
computer assistance
closed-circuit tv
overhead projector
16 mm film; wall charts; maps; tackboards chalkboard
evolving pattern

2.1 Graphic description of evolving patterns in facilities, technology, program, and student-staff relations. Arrows show general trends from traditional (base) to emerging characteristics, with descriptions ordered in approximately the sequence of development observed by the study team.

Our study was focused primarily on elucidating those attributes of secondary school science associated with patterns 1 and 2, facilities and technology. However, there were interesting interactions and contrasts between the various patterns. For example, we observed that more advanced forms of programs and of student-staff roles were present in some schools with comparatively poor facilities. In other schools, we observed good (that is, versatile and compatible with individualized instruction) facilities or good technology but relatively low-quality program planning and/or relations between students and staff. No school was observed where all four patterns were at the most advanced level, although seldom did a school excel with respect to one pattern while being essentially at the lowest levels with respect to the other three.



program

integrated science:
heterogeneous age grouping

student planned learning
activities

criterion referenced

study units:
individually paced; single
discipline; single age group

norm referenced

alternate experiments;
special readings

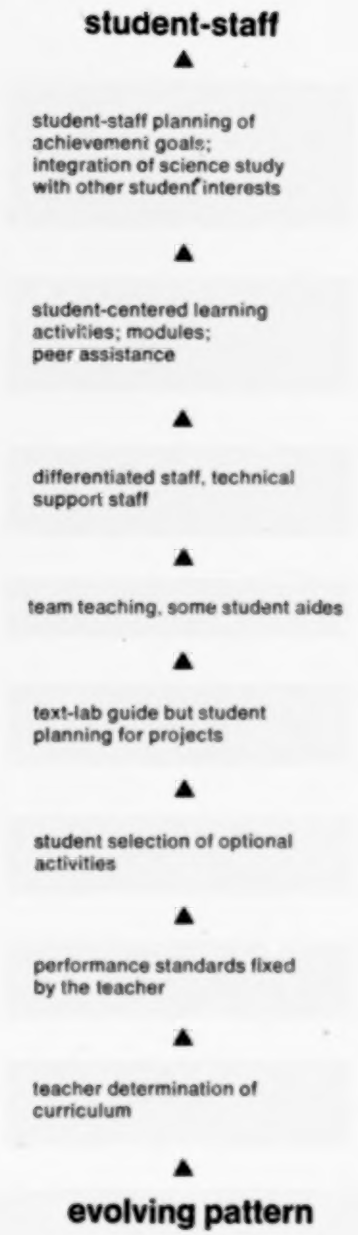
study unit packages:
group schedule

extra credit or honors work

tracking: programs for
high and low achievers

single-subject; text-lab program
group paced; group exams

evolving pattern



student-staff

student-staff planning of
achievement goals;
integration of science study
with other student interests

student-centered learning
activities; modules;
peer assistance

differentiated staff, technical
support staff

team teaching, some student aides

text-lab guide but student
planning for projects

student selection of optional
activities

performance standards fixed
by the teacher

teacher determination of
curriculum

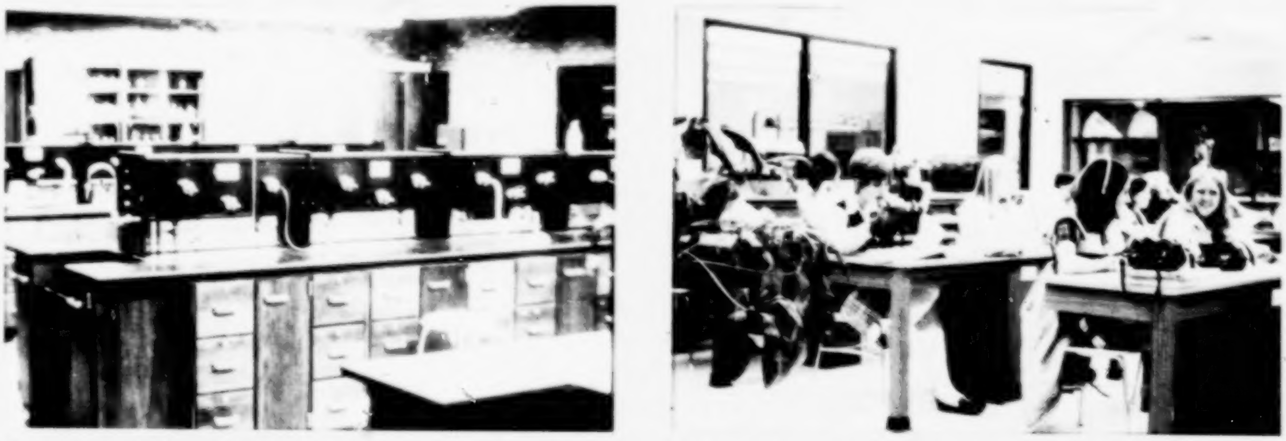
evolving pattern

Patterns in Facilities

The evolving pattern for facilities derives in part from assumptions made in selecting "exemplary" schools and input from observations made at the schools. We assumed that **flexibility** in use of space and equipment was important; we also assumed that increasing provision for **individualized** study will be sought in schools in the future. Other assumptions might have led to a different ordering of facilities observed. For example, if a major criterion was the degree to which facilities permitted complex experimentation, including the use of reasonably sophisticated equipment by all members of a class, some facilities that rank low in the pattern we describe would rank higher or even near the top of a scale based on this assumption. But we believe our assumptions were substantially in agreement with the goals teachers are seeking. The experimentation criterion was cited primarily in regard to special project work and for relatively few students.

Laboratory work for science programs in the past has required simultaneous experimentation by all members of the class. This meant that an experiment dealing with Ohm's law required as many sets of equipment as there were students, or at least one set for every two or three students. Similarly, a study of frog anatomy would require stacks of dissecting pans, one for each student. In many ways, good laboratory facilities for science programs based on a uniform curriculum and schedule require a much greater investment in furniture and equipment than do programs that are individualized, both in choices of experiments (or demonstrations) to be performed and in pacing. Generally speaking, two or three set-ups for a given experiment often will suffice for 50 or so students in an individualized program. But a greater variety of experiments may be offered in individualized programs, and the logistics of providing materials and equipment become significantly different and more complex. In Chapter 5 the problems of supply logistics are dealt with in some detail.

Figure **2.2** illustrates various kinds of science facilities arranged in an evolving pattern. Separate lecture and laboratory rooms, massive laboratory benches, and single-science laboratories often represent minimum potential for flexible use of space. Although individualized, student-paced instruction is possible (and indeed practiced by some teachers) in this type of facility, only those schools comparatively well endowed with equipment and materials as well as with low student-teacher ratios (12 to 16 to 1) manage this technique successfully. More typically, facilities of the type shown on the left side of Figure **2.2** are used for group teaching with little provision for individual differences.



From separate lecture and laboratory rooms with fixed furniture ▶ to rooms for lab-discussion with movable tables ▶ ▶ ▶ ▶ ▶ ▶

2.2 Evolving pattern in facilities.

Intermediate between facilities with massive, fixed furniture and flexible open styles are many alternatives. Rows of fixed tables or lab benches are perhaps the most common pattern, with these facilities used both for laboratory work and lecture-demonstration. Perimeter arrangement of laboratory benches may accompany rows of chairs for a central lecture area. Increasingly, this type of facility has movable tables in the central space, allowing for various types of group or individual study. Peripheral laboratory facilities with large open central areas can be found in newer schools, usually accompanied by some form of student-paced program and / or integrated science curriculum.

Special project areas or small-group seminar rooms are adjacent to open laboratories in the best facilities, with plant-growing and animal rooms conveniently located next to the laboratory. Stockrooms are large and have adequate space for preparation of materials by teachers, student aides, or technicians.

The move to differentiated staffing is evident in many of the schools visited. Schools with traditional laboratories may only use supporting staff for maintenance of a greenhouse or a planetarium. Schools with individualized programs and substantial instructional technology may employ a variety of support staff. In most cases the student / teacher ratio increases when other support staff are available, with a typical pattern being about two full-time technicians to one teacher. This arrangement appeared to be well received by teachers, although technicians sometimes expressed concern with their salary levels or opportunities for advancement.

Obviously, the four evolving patterns are linked to each other. Facilities with separate lecture areas and massive, fixed furniture tend to be used in situations in which students are not involved in curriculum decisions, in which technological aids are used only for group instruction, and in which competition for grades is emphasized over the pursuit of specified skills and cognitive competencies. Some teachers and some school administrators do wish to minimize student involvement in decision-making with respect to curriculum as well as in alternative modes of instruction. Our conversations with teachers and administrators, however, indicated that most were striving to accommodate individual student differences. The major difficulty restricting further progress toward this goal often was not facilities or resources but lack of knowledge of how to use existing resources more effectively.

Large, open, multidisciplinary science facilities cannot be used effectively without supporting staff, and an individualized program requires additional clerical or other aides. And yet, the total costs for these programs can be **less** per student than the costs for restrictive traditional programs. When new construction is planned, cost benefits can be substantial with open laboratory programs. Nevertheless, deciding on this type of facility requires careful consideration of the other three patterns.

▶ ▶ ▶to large open laboratories for all science subjects ▶ ▶ ▶ ▶ to flexible labs and adjacent, carpeted discussion-study areas

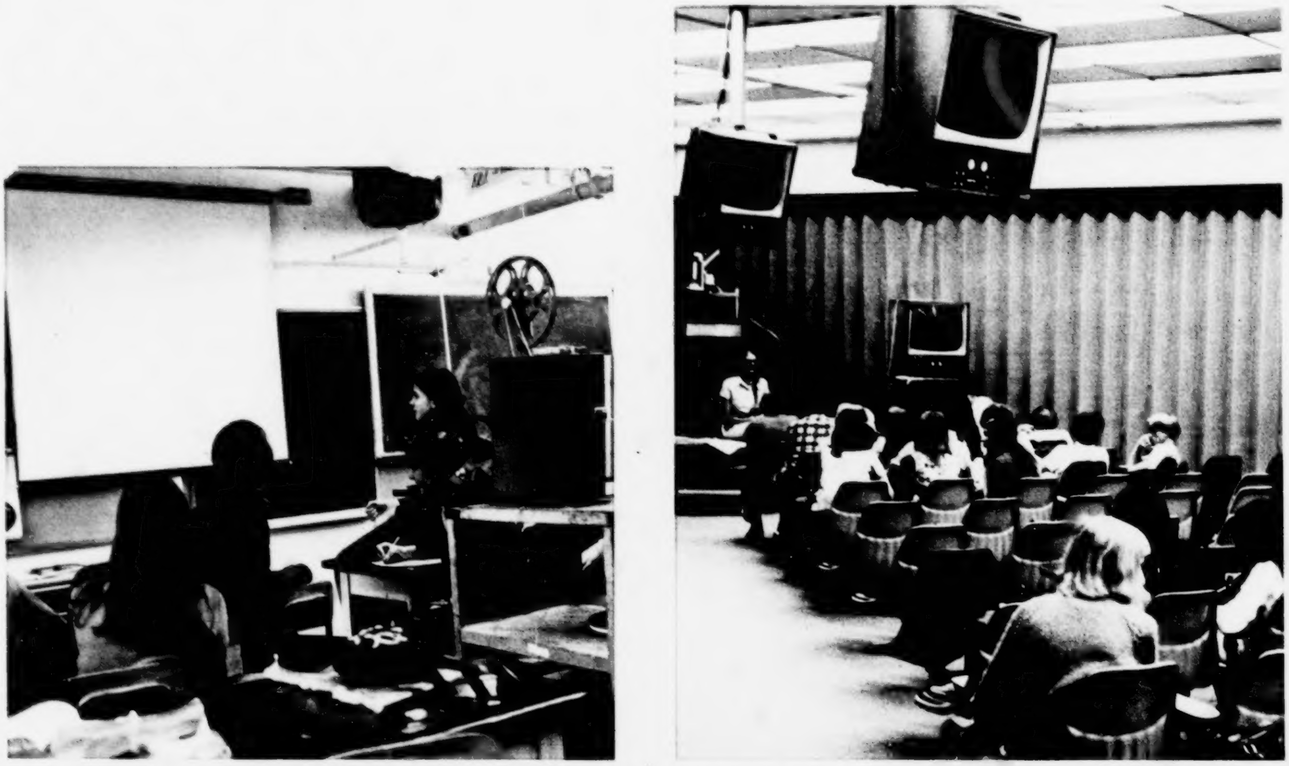
Patterns in Technology

Patterns in Technology
Figure **2.3** shows some of the instructional technology available for the second emerging pattern of science instruction.

The simplest, and still important, form of instructional technology is the chalkboard, although the traditional gray slate blackboard has given way to various synthetic materials in several colors. Some rooms have walls where the entire surface can be used as a chalkboard. This ancient teaching aid continues to be useful and surely will always have its place in schools. We see no sign of extinction for the chalkboard.

Wall charts, maps, and tackboards also continue to serve as important instructional aids. In exemplary programs these aids are used primarily for small-group instruction, for small groups of students working together, and for *occasional* lectures. This means that the type and location of these aids usually differ from types and locations in traditional classrooms. The back surface of a rolling cabinet may be a chalkboard or tackboard. Charts and maps may be displayed in corridors where extensive wall space is available and where students can have easy access to the materials for reference study.

Overhead projectors were found to be useful in many schools visited. Originally introduced largely as a substitute for chalkboard space in traditional lecture presentations, the overhead projector is now more commonly used for special demonstrations [5] or by small groups of students working with specially prepared transparencies.



From chalkboards, 16mm film and closed-circuit television for group instruction ▶ ▶ ▶ ▶ ▶ ▶ ▶ ▶ ▶ ▶ ▶ ▶ ▶ ▶ ▶ ▶

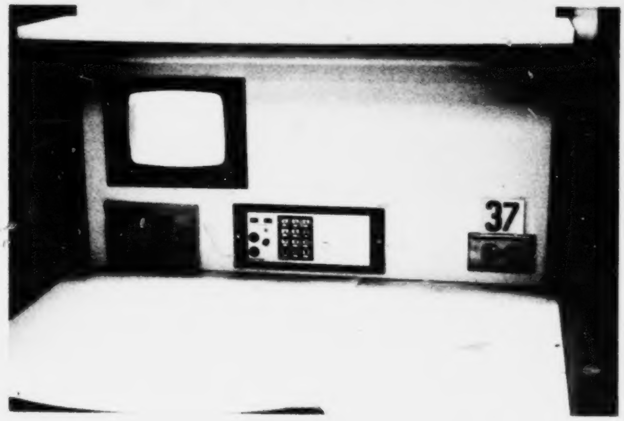
2.3 Evolving pattern for instructional technology.

When 16mm films became widely available for school use in the 1930s, some teachers feared that their jobs could be lost because of this technological aid. Today we observe a declining use of 16mm films, partly because good films are expensive and hard to obtain and partly because shorter, less expensive 8mm or Super 8 films present many advantages for individualized programs. Nevertheless, there are some very fine half-hour or longer 16mm films, and these will continue to be useful in science teaching. Increasingly, these longer films are used only as a form of enrichment, with short Super 8 films used as the primary means for showing motion where time-lapse or high speed cinematography can be used to present important concepts. Shorter 8mm loop films allow students to make observations in small groups or as individuals and to repeat these observations to the extent needed. Scenes that do not require motion to present information (constituting the major part of most long 16mm films) may be viewed as slide sequences or as filmstrips, again by individuals or small groups with as much repetition as desired.

Closed-circuit television began to appear in schools in the 1950s. With the subsequent development of economical video-tape recorders, this technology presented some logistic and cost advantages over 16mm film. Any number of classrooms could view a lesson simultaneously, and film plus projectors did not need to be transported from room to room.

We observed television monitors in the science classrooms of several schools, but not one study team member saw one in use in the science program. Exemplary science programs find the classroom TV screen too limiting for group presentations and unsuitable for individualized study. For science instruction, closed-circuit television appears to be headed for extinction. However, the video-tape recorder is becoming an important tool when used by teachers and students to improve the processes of teaching, discussion, and interaction.

▶ to dial-access TV and audio tape in learning centers ▶ ▶ ▶ ▶ to student controlled A-V equipment in science facilities



Patterns in Technology

Dial-access television and dial-access audio were observed in a number of schools. This equipment requires substantial investment in technical support staff as well as in capital outlay. The advantage is that **individual** students can obtain a given TV or audio signal simply by dialing the appropriate code. Switching equipment in a control center automatically activates video- or audio-tape decks, and the signal is transmitted to a student's carrel. But — and this is important — even the most elaborate systems observed in secondary schools do not permit a student to stop the program, back it up, and repeat segments. If one student has already dialed a lesson, a second student must wait until the lesson is over or "pick it up where it's at." Increasing the number of video and audio playback decks can reduce this problem, but at a cost of $4,000 per TV deck or $500 per audio deck. The necessary switching equipment and technical support also add to costs. Most school systems find it impossible to consider this form of technology as school budgets are now structured.

Some of the present technical limitations in dial-access equipment could be overcome; decks could be designed that would allow a student to stop a program, back it up, and then continue. Color TV, rather than black and white, as now commonly used, already is employed in some systems. Good commercially produced TV lessons might resolve some of the problems teachers now face in preparing videotapes for the dial-access system. Cheaper and more reliable switching equipment will undoubtedly appear.

Only rarely did we observe science students using dial-access TV in those schools where this technology was available. Our observations and conversations suggested that science teachers often found other combinations of teaching aids better suited to their purposes, especially where observations on materials or instruments were desired.

We cannot predict the future value of dial-access systems for science instruction. For those schools that have decided to include this technology, we urge science teachers to find effective ways to use the facilities. Although costly in capital outlay and technical support by present-day budget standards, the $6 to $10 per pupil per year that this system requires as a minimum does not appear unreasonable when it is recognized that per pupil costs in these school systems may be $1,000 per year or more. For the near term, however, we see other forms of technological assistance as showing more promise for facilitating science instruction.

Computer-assisted instruction (CAI), already tested in a number of schools, has the capability of sequential presentation modified according to the learning patterns of the individual. Program preparation costs, however, are very high, and computer lease charges can also be prohibitive. At best, present CAI modes cost about $5 per student per hour. We observed some simple CAI instruction, but mostly in mathematics class work. Undoubtedly, computers can now play an important role as aids to students, but the widespread use of computers for tutorial instruction in science is at least one decade and probably more like three decades away

Perhaps most promising is the use of simple technological aids used in various forms of audio-tutorial or student-controlled instructional programs. Good, inexpensive cassette tape recorders now available permit a wide range of audio-guided, individualized study. Motion pictures can be used with several easily prepared versions of audio guidance to illustrate selected principles; slides, filmstrips, or diagrams can be studied similarly. Laboratory techniques can be taught with the combined use of simple A-V aids and mock-ups or actual items of equipment. The almost unlimited combinations of printed, visual, simulated, and actual objects that can be assembled in individualized instructional modules suggest that this type of technological augmentation is only in its earliest stage of evolution and will become increasingly important to science instruction.

In terms of costs, small cassette recorders (about $35 each), slide viewers ($5 to $10 each), and some use of cartridge Super 8 film projectors ($110 to $120 each) are easily within the range of present school budgets. An important advantage of combinations of simple technological aids is that schools can expand their investment gradually, thus allowing for the coordinated development of instructional programs with the extended use of technology.

Simple technology for individualized instruction presents another significant dimension to be considered. Students can and do work with teachers or other staff members to design or revise instructional modules. The instructional tools represent a medium for both students and staff to use in exploring better ways to master important skills and concepts. [6] This type of technology, properly used, can encourage extensive human interaction, with comparative efforts targeted at mastery in learning rather than interstudent competition for high position "on the curve" in grading.

Although we show simple technology as the most advanced form for schools, it should be recognized that this kind of support is in comparatively easy reach for most schools. Optimal levels of equipment and support staff would cost $5 to $8 per child per year, less than the cost of dial-access systems, but would make possible broad ranges of new, individualized instructional practices. As already suggested, investment in the program could be expanded gradually, beginning at the traditional level. Moreover, it is unnecessary to move through expensive closed-circuit or dial-access television systems in the course of technological expansion. The opportunity to leapfrog on technological support of instruction should be good news to teachers and administrators.

Students as well as teachers need to learn alternate ways of using textbooks and other materials together with technologically mediated materials. Unless inservice training is provided, even simple technology could lead to less humanistic school learning and to emphasis on rote memorization rather than on concept learning and problem-solving skills.

Construction and maintenance costs for open schools are substantially less than for traditional buildings. If technological support and appropriate furnishings are planned at the time of new construction or remodeling, the savings from open design can more than pay for all costs in media and technical support.

Again, however, we must stress the interrelationship between the four patterns. Communities that plan for open schools but fail to provide teacher training, equipment, and technical support may wish they had built a traditional facility. The temptation to move to open school construction merely for cost savings should be avoided. Without reinvestment of some of these savings in technical support and program development, widespread dissatisfaction among school personnel, students, and the community could result.

Patterns in the Science Instruction Program

There is a definite need for detailed study of exemplary science programs, but this was not the purpose of our study. And yet, much of our time in schools was spent discussing with teachers what kinds of science offerings they had, the textbooks or syllabi being used, their perceptions of needed new curriculum material, and the apparent succeses or failures in their present programs. Discussion of any feature of laboratory furniture or room arrangement always elicited teachers' remarks pertinent to the instructional program.

As our observations of schools progressed, we began to discern a pattern in the kinds of comments teachers were making about their science programs and the kinds of satisfactions or dissatisfactions they expressed about the facilities. For example, we were visiting schools during a time when concern for preservation of our environment had become a popular crusade. Many teachers indicated that they wished to do more in the area of environmental study; some had begun to develop natural areas on or near their school grounds; some already had such areas and were using them in new ways; and some described their plans for new ecological study areas. It was evident that many teachers were seeking new or better facilities for teaching concepts important to the understanding of the environment. But we also observed the vestiges of past crusades: a little-used laboratory, planned during the height of public interest in space exploration; massive laboratory benches with extensive plumbing and other mechanical supplies designed for the days when ideal science instruction required that facilities closely approximate those of research laboratories; and extensive stores of expensive equipment for the same research purposes.

Some of today's patterns have interesting counterparts in the past development of science education. When science instruction first became common in secondary schools in the nineteenth century, courses were often labeled "Natural Philosophy" or "Natural History." The subject matter ranged over all fields of science. Most courses attempted to show the order and beauty in nature, primarily to illustrate the power and wisdom of our Creator. As knowledge in the science disciplines increased and public secondary schools became more secular in their total program, courses in botany, zoology, physics, and chemistry began to displace "traditional" courses in natural philosophy or natural science. Science education moved from general courses to programs with courses in specific subjects; i.e., science curriculum moved from a general, integrated study of natural phenomena to study of facts and principles specific to one of the science

From group teaching, single-subject classes ▶ ▶ ▶ ▶ ▶ ▶ to large-group and small-group programs ▶ ▶ ▶ ▶ ▶ ▶ ▶ ▶

2.4 Evolving pattern for science programs.

disciplines. Some reversal of this focus on specialized science subjects began about 1910 when courses in biology began to displace courses in botany and zoology and continued in the 1920s when general science began to appear. However, biology courses in the first half of the twentieth century presented little from the physical sciences that could lead the student to see a basic unity among the sciences. General science courses were usually offered at the junior high school level and consisted of little more than watered-down versions of high school science subjects connected only by the fact that the topics were studied sequentially during a single school year.

In search of those program elements that might meet present needs and have lasting versatility, the study team increasingly zeroed in on features that were less related to the specific content taught and more pertinent to the roles students, teachers, and staff played in the program. Figure **2.4** illustrates these features in the evolving program patterns.

▶ **to student-centered, student-paced programs** ▶ **to differentiated staffing, heterogeneous age group, and individualized programs**

Patterns in the Science Instruction Program

We observed a renewed interest in the integration of science subjects and in attempts to handle broad concepts or to find other unifying frameworks. In some schools, several years of teachers' efforts, often supported by summer salary grants, have been expended in developing a curriculum that presents science as an integrated sequence. Rather than in the usual sequence of biology, chemistry, and physics, students enroll in Science One, Science Two, and Science Three as they progress from the sophomore to the senior year. Various patterns of integrated or fused science offerings are found. Since little state or federal money has been made available for this type of curriculum work, efforts have been largely restricted to the personnel and financial resources of a single school or school district. None of the well-financed curriculum projects supported by the National Science Foundation from 1955 to 1970 was an interdisciplinary program for high school students. [7]

Some schools have continued programs in the separate disciplines but have moved to individualize the courses by preparing study packs or learning packs. These units of study include didactic as well as laboratory aspects of the course. Students progress at self-paced rates through the study units, with some students completing the minimum or basic units much sooner than do other students.

Learning packs or other forms of student-paced science programs are usually accompanied by evaluation procedures different from those used when the entire class is proceeding at the same rate through the same curriculum. *Criterion*-referenced testing is employed rather than *norm*-referenced testing. (Briefly, the difference between criterion-referenced and norm-referenced evaluation is as follows: In *criterion*-referenced evaluation each student is asked to achieve a well-defined set of learning objectives at some specified level of proficiency, each student works to meet the criterion level of proficiency required. In *norm*-referenced testing, each student is in competition with his classmates for some position on the class distribution of scores on a given exam; students are competing with each other for a position "on a curve." This system has been common in schools.)

James Block has compiled some important references and papers that describe the distinction between criterion-referenced evaluation and norm-referenced evaluation in his book, *Mastery Learning: Theory and Practice*. [8] Mastery learning, a term commonly used in discussions about evaluation, denotes that students are required to attain a set of learning objectives to some level of *mastery*. In practice, mastery learning used with learning packs means that students must obtain 80 to 90 percent success on evaluation materials (usually paper-and-pencil tests) for a given learning pack. If they fail to perform at this level, they must restudy materials, repeat experiments, or do alternate studies pertinent to the unit until they reach or exceed the criterion of mastery. Students may repeat a test on a given unit two or three times; commonly the evaluation materials used are not the same for the test repetitions.

From a psychological point of view, the practice of learning for mastery and associated criterion-referenced testing has much to recommend it over traditional norm-referenced evaluation. Students can proceed more slowly on those study units or sections of units in which they lack adequate background. Too often in conventional instruction, students must move on to new topics before they have mastered earlier topics. Because concepts presented later in science courses frequently build on earlier concepts, students who did not achieve adequate mastery of these earlier concepts become progressively more overwhelmed. As can be predicted from known requirements for new cognitive learning, students who fail to understand earlier concepts are almost certain to lack the necessary cognitive structure to acquire later concepts. Moreover, frustration realized during earlier failures interferes with subsequent learning of new concepts, even when these concepts are not sequential to and do not require mastery of earlier concepts.

Another salient argument for mastery-learning programming is that it fosters cooperative efforts among students. Each student is competing with himself to master some defined learning objectives. As teachers know, helping others learn is one way to achieve mastery of a subject while concomitantly gaining emotional satisfactions derived from helping others. Increased clarity of the learning objectives, no undue pressures to complete many additional study units, and a classroom climate of openness and friendship contribute to positive gains. Unfortunately, too few college courses operate in a fashion to train teachers, through example, in these skills. Only slow progress in this area is occurring in colleges and universities. This problem is discussed further under pattern 4.

Modular scheduling was generally the rule wherever individualized instruction was the practice. In this form of scheduling, the school day is normally divided into 15 to 30 time blocks or "mods." Most commonly, mods are 18 or 20 minutes long, and a student may schedule himself into a class for one or more mods. Another feature of modular scheduling is that students may schedule a subject for three or four mods one day and zero or one mod on another day. Moreover, in most schools with modular scheduling, 30 to 50 percent of the mods are left unscheduled. During these times the student may perform laboratory experiments, participate in art or other activities, work in the learning center, or — in some schools — go home.

In high schools with 2,000 or 3,000 students the number of unique schedules becomes almost infinite, and computer planning of schedules is necessary. Schools planning to introduce modular scheduling must budget for computer services *and* competent consultant assistance; otherwise modular scheduling could prove a nightmare.

Also, in modular scheduling, schools must guard against filling the schedule too full. There must be sufficient time for teachers and pupils to interact and for students to have lab activities when needed in the learning sequence. Overcrowded schedules will reduce student options rather than increase them, and create more rigidity rather than less through the repetition of the same pattern. Schools may find more flexibility in longer time periods assigned to a team to subdivide as needed each day or week.

A few of the schools we studied employed, to some extent, all of the newer program dimensions described in this section: individualized study with some form of learning packages, an integrated science program, criterion-referenced evaluation and mastery-learning practices, encouragement of student cooperative learning, modular scheduling and considerable freedom for the student to plan his activities each day. Unfortunately, some of these schools were handicapped by less than optimal science facilities and some employed little or no advanced instructional technology. We based our definition of *evolving patterns* in part on the observation that these same schools recognized and were seeking the potential improvements in instruction that could accrue from more and better technology for individualized instruction and from facilities that allowed greater flexibility in use from student to student and from day to day.

We also observed some schools in which program practices had begun in the direction described, but had reverted to more rigid scheduling and / or less flexibility in students' programs. Where this was conspicuously the case, the problems evident were less often related to facilities or technological resources than to the existing pattern of student and staff relations. It is imperative to recognize the close interaction between patterns of facilities, technology, program, and student-staff roles. The parallel to biological evolution is suggested as an analogue. Organisms advance through adaptations in structure, physiology, reproductive mechanisms, and through extended habitat ranges. Each of these dimensions is intricately dependent on the others. Chances for survival and proliferation are enhanced by advances in all dimensions. Flexibility or adaptability is the key to survival in the biological world; flexibility or adaptability in science facilities and programs is vital to education.

Patterns in Student-Staff Relations

The most difficult evolving pattern to illustrate is the observed trend toward increased **humanism** in schools. This pattern is characterized by a move from teaching with an emphasis on subject matter to various forms of group and individual associations that emphasize emotional as well as cognitive growth of each child. (See Figure **2.5**.) While some teachers have achieved a climate of humanism in traditional lecture-laboratory science instruction, the potential for warm human interactions between staff and students and among students is greater with facilities and programs at the "upper end" of patterns described earlier. It should be noted, however, that open schools with technology for individualized instruction and programs that allow diversity in the selection of study units and rate of progress do not necessarily ensure an increased climate of humanism in a school. If technology is used in such a way as to reduce contact between students and staff, it is dehumanizing.

The traditional instructional pattern, employed in most schools, places primary emphasis on completion of teacher-planned assignments in textbooks and laboratory guides. There may be cooperative planning among teachers as to which chapters of the text will be presented when, but this planning more commonly serves logistics purposes rather than educational goals. Decisions regarding such matters as who will use what laboratory facilities on which days and when the supply of frogs for dissection should be ordered characterize these planning efforts. Students are not included as participants in this planning nor is any significant attention directed to the needs of individual students.

Sometimes traditional planning efforts include new ways to divide the student body into lower and upper tracks or other attempts to lessen the heterogeneity in classes. From the standpoint of psychological impact on students, tracking can be a major contributor to poor student and staff morale. It may be devastating to some individuals pushed by their parents or denigrated by the labels applied to them.

From teacher-dominated group instruction ▶ ▶ ▶ ▶ ▶ ▶ to larger, mixed groups ▶ ▶ ▶ ▶ ▶ ▶ ▶ ▶ ▶ ▶ ▶ ▶

2.5 Evolving pattern for student-staff relations.

School facilities designed and used for self-contained class instruction too often direct planning toward tracking programs. (While it is possible to use traditional facilities in individualized programs, our observation was that this seldom occurred.) The most a student can hope to be involved in planning his education is that he may influence the gross decision on the track to which he will be assigned. In this case, he gets a chance to choose on which curve he will be placed when grades are assigned.

A second stage of student-staff relations allows the individual student to select optional exercises, readings, or laboratory experiments. In programs where tracking is employed, these options are sometimes available only to students in the academic or college-bound track, or only to the higher achieving students in a given track. Curiously enough, students who are demonstrating either a lack of interest or success with assigned lessons may be given the *least* opportunity to select alternatives.

In a third stage in student-staff relations the instructional program is based primarily on a textbook and laboratory guide but students are significantly involved in planning for major projects, field experiences, or long-term programs. Two good illustrations of this type of arrangement are the joint teacher-student efforts to create a natural area on a school plot in California and the space science activities of Project SPARC at Northeast High School in Philadelphia.

▶ **with paraprofessional support staff ▶ ▶ ▶ ▶ ▶ ▶ ▶ ▶ ▶ to student-centered, student-selected programs**

Patterns in Student-Staff Relations

Where team-teaching methods were employed, we observed a pattern of student-staff relation that involves several different roles. Large lecture sections may combine several classes to hear one teacher present a topic on which he is presumably more expert than are his colleagues. Laboratory or discussion sessions may be smaller groups than normal, perhaps 12 or 15 students rather than 25 or 30. A laboratory technician may aid the teachers in the preparation of materials and assist students in laboratory activities. The staff of the library or learning center may also be involved in the program. Thus, students experience several kinds of staff associations and meet with their peers in more than one type of grouping.

Typically, a team-teaching program is associated with norm-referenced grading and tracking, but some schools have moved to mastery-learning models and some student-paced instructional schemes.

A few schools that employ norm-referenced evaluation have programs that allow students extensive opportunity for involvement in selection of study material and also a variety of student-staff or student-student associations. Increased involvement by students in selecting and pacing their studies usually occurs in programs in which criterion-referenced evaluation is practiced.

Evaluation practices are of particular importance in patterns of student-student and student-staff relations. It is difficult to foster warm relations between students when they view themselves in competition with one another; it is difficult for staff members to play the role of sympathetic facilitators of learning when they will draw the line that labels one-third or one-fourth of the students unsuccessful.

In another program variation, relatively traditional textbook-laboratory programs can be used as the curriculum base for individualized, student-centered instruction. For many years some teachers have employed various forms of "unit" constructions that allow a student to progress through the reading and laboratory work of a given unit at his own rate. The logistics of supplying needed materials and assistance becomes difficult with larger classes, and instruction tailored for individual students is usually limited to small, rural schools. We did not study any such schools in conjunction with this project. The "one-room" schoolhouse permitted not only accommodation to the rate of progress a student could make but also close peer-peer association and heterogeneous age grouping in a given subject area. Supported with modern materials and instructional technology, the one-room school model would have much to recommend it.

Schools that place major importance on permitting students to proceed at their own rate employ some form of individualized study units, "learning activity packages," "minicourses," or study modules. Evaluation is based on achievement of some level of mastery as required for each unit. Teachers encourage students to move ahead and may give various forms of special help to those who are far behind. In fact, most teachers report that with student-paced study units, they spend most of their time assisting slower students. This is especially so if reading choices and levels are not varied in the available units or if too much emphasis is placed on reading as a source of information. With well-designed "learning modules," good students race along with a minimum of assistance. Occasionally, better students are asked to assist peers who are having difficulty. When properly used, this practice can have positive, humanizing results for all concerned.

We are now beginning to observe the emergence of another form of student-staff relations — students playing a major role in planning and developing instructional modules. While this has occurred in special project areas (as mentioned for Project SPARC), the emerging form involves students in development of the basic core of learning materials. Availability and use of relatively simple technology greatly augment this form of student involvement. Inexpensive tape recorders, projectors, and associated audiovisual materials can be used by students in highly effective audio-tutorial study units. Moreover, this kind of student involvement can take place in traditional "egg crate" school buildings or in new "open" schools. Some new investment in facilities is needed, but the dollar costs are in thousands and not hundreds of thousands as for dial-access or computer-assisted programs.

Students who design and redesign a lesson module for use by their peers confront the challenge of learning with very different perspectives than those of students who are given assignments in a textbook or laboratory. As modular scheduling increases, the potential for extensive heterogeneous age groupings will increase. Many new opportunities for student involvement in the process of teaching will undoubtedly occur. Those of us who have had success in planning instruction for fellow human beings and who have observed their pleasure when they succeed in learning know this as an important expression of love. Educational practices that increase ways for students to express feelings, to express love, may lead to substantially different citizens than our schools have produced in the past. We believe this goal is too important to obscure by emphasis on brick and mortar and technology. We profoundly hope every reader of this report will share in this concern.

We cannot leave the discussion of the evolving patterns and especially the matter of humanism in education without mention of the relations between the community and the schools. Community interest and support of schools vary widely from system to system. When communities express confidence in the administration and staff of the schools, considerable freedom in development of program and facilities may be possible. With a generally critical or hostile community attitude toward schools, there is little chance to develop individualized programs that permit extensive student participation in decision-making. The cycle of public dissatisfaction with schools, leading to extensive criticism and/or less financial support, leading to reduced staff, and poor student morale, leading to less effective instruction can "spiral down" to the point of school closings. While this downward spiral often reflects poor communication with the community, it may also be accelerated by poor decisions in school building, inappropriate investment in technology, selection of inappropriate programs, or breakdown of relations between students and staff.

We also urge every reader of this report to note carefully that "open school" plans that do not include reasonable levels of technological support, programs for individualized instruction, and training programs for staff that will assist them to work with students as individuals could lead to disaster. We do not recommend that communities build facilities or employ technologies at the higher levels described unless they are prepared to individualize programs, place emphasis on each student as a unique and valuable human being, and prepare students and parents for and in the change process.

The validity of the evolving patterns described can be tested. We as a team recognized that these patterns were apparent in our school observations but that there could be other patterns. Moreover, our analysis was horizontal with respect to time. It would be valuable (and we hope possible) for other study teams to review school science programs five or ten years hence and to observe what changes have occurred. We submit this description of these patterns partly as a report and partly as a hypothesis to be tested in the future. We challenge educators to evaluate their own programs against the models presented and to report agreement or disagreement.

How to Use the Evolving Patterns

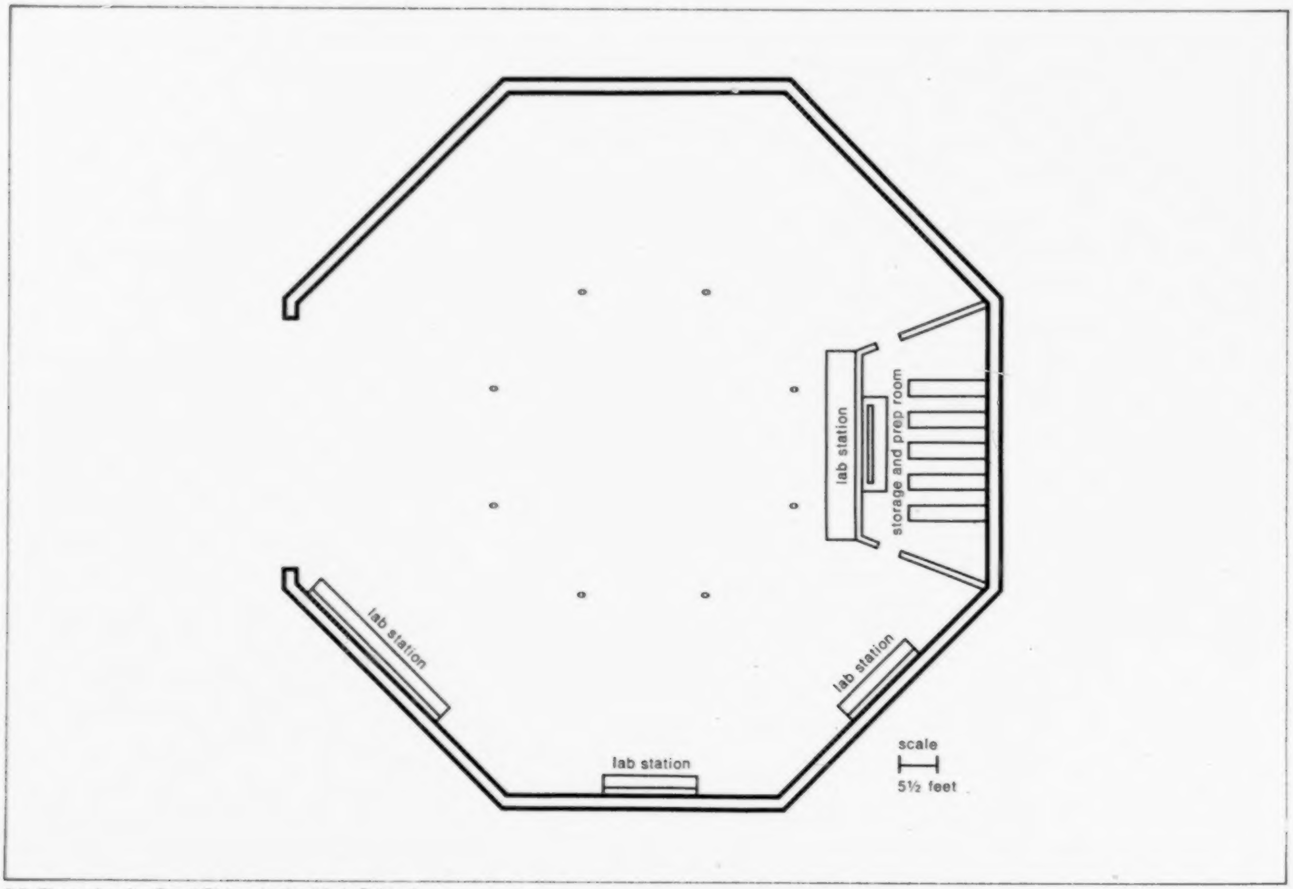
In our view, every science program could benefit from a staff assessment based on the evolving patterns described in this chapter. To illustrate how this might be done, we will describe programs from two schools visited and diagram their status on the evolving patterns scheme.

Sand Ridge Junior High School in Roy, Utah, enjoys the advantages of a new building with a large, fully carpeted, open science area. The floor plan is shown in Figure **2.6,** and a view of the facility, in Figure **2.7.** Study-work tables provide space for individual and small-group work. "Wet" laboratory activities may take place at benches near the stockroom and at other locations. Seventh-, eighth-, and ninth-grade students work independently or in small groups using the Intermediate Science Curriculum Study (ISCS) program as the basic study material.

As a facility, Sand Ridge would rate near the top on our scheme. The facility has almost unlimited flexibility for interdisciplinary, student-paced study. Central storage of equipment provides for an efficient supply of a wide variety of materials. Ample space is available on the school grounds for planned development of a natural environment. The lack of small seminar or project rooms adjacent to or within the science area could be considered a limitation.

Technological support is reasonably limited. Study carrels are available in the learning center adjacent to the open laboratory. Tape recorders, filmstrip viewers, and other equipment are used. Technologically mediated study units in science are not available, but much potential growth could be realized even in the use of present facilities.

Students progress through the program at their own rate. However, teachers encourage them to move ahead and provide considerable assistance to students who are making slow progress. Testing is criterion referenced, and students' records are carefully maintained. So far, there are only limited opportunities for alternate study materials. As more learning resources become available, many more study options can be developed. With modular scheduling, students can adjust the time in the science facility according to their needs and desires. We observed considerable peer-peer assistance, and multi-age groups were commonly working together. With future program development, we foresee student participation in various phases of curriculum planning.



2.6 Floor plan for Sand Ridge Junior High School.

Although the new physical plant at Sand Ridge immediately conjures up a positive attitude, the impressive high morale of this school is primarily a result of excellent student-staff relations. The principal has his "office" in one corner of the student commons area. When he is at his desk, he is accessible to anyone. More commonly, the principal is assisting students and teachers in one of the learning areas. The science teachers work together and are available to any student. They are assisted by a competent technician who maintains the stockroom and works with students who earn part of their credit preparing materials or performing other stockroom duties. A secretary maintains records for all students in science, scores some portions of exams, and helps in other ways. Students frequently assist one another, and student-staff cooperation is conspicuously good.

Sand Ridge may benefit from the advantages of a new building. However, many other new schools were visited, and rarely did we find facilities, program, and student-staff relations so well combined. There is room for improvement, and we would expect to see advances in program and facilities in the future. At this time, Sand Ridge Junior High School ranks high in our study of exemplary facilities and can serve as a model.

In contrast to Sand Ridge, some new schools with expensive installations of furnishings and technology continued with teacher-dominated, group instruction using traditional textbook-laboratory programs. A broad array of problems were evident in these schools, but sometimes future plans did not include new approaches to humanize the environment.

Older facilities were also visited. Some had undergone recent remodeling and possessed one or more outstanding features. Excellent programs have been developed by hard-working teachers, and these programs are succeeding with individual students in spite of limiting facilities or lack of technological support.

2.7 View of science facility at Sand Ridge Junior High School.

How to Use the Evolving Patterns

Of the older schools visited, Wilson School in Mankato, Minnesota, was exceptional as an illustration of what could be done. Wilson is the laboratory school at Mankato State College, and, therefore, somewhat atypical of other schools. Changes here began in the area that is most important: relations between students and staff members. The focus of all changes was to improve the learning environment for each and every student.

Within a traditional building, new learning areas were created simply and inexpensively. Doors were cut between rooms to allow new uses for rooms or portions of rooms; some hallways became parts of new learning areas, independent study, or project space when and where new cubicles were needed. In short, Wilson School became an "open school" by opening up rooms and hallways, but primarily by allowing students to move freely to those areas where their work could best be done. The school serves as an excellent example of how old buildings can be used in new ways with modest investment. Instead of preventing new instructional approaches, the traditional rooms with some modification made very nice combinations of spaces for everything from quiet study to group discussion or noisy project work.

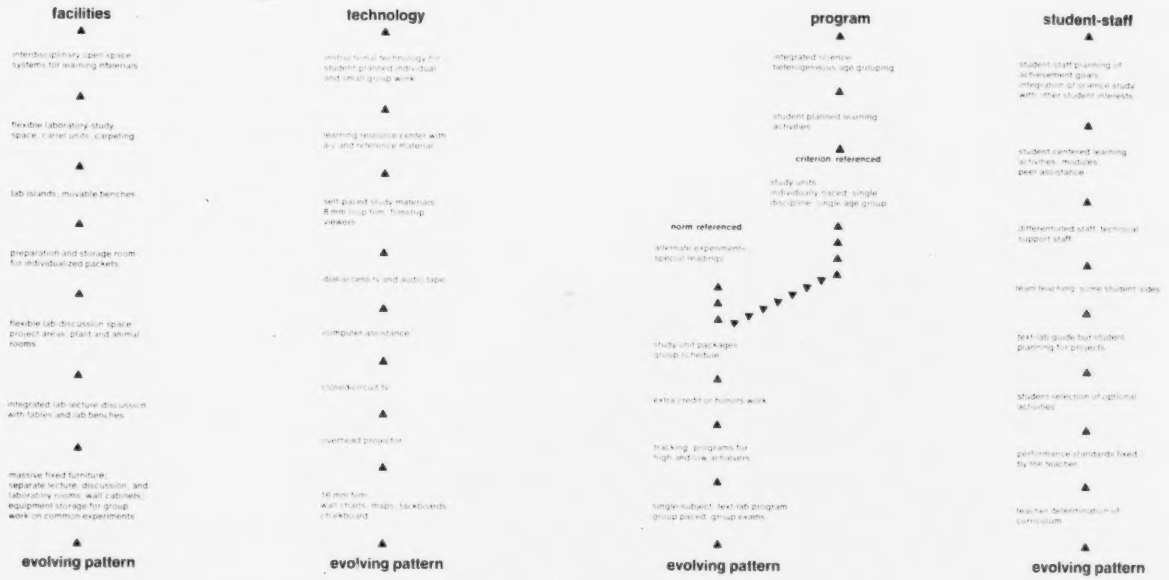
In terms of the evolving patterns model, Wilson School ranks very high. (Figure **2.8**) Although most of the facilities are old, they are used to good advantage and permit a wide variety of individualized, interdisciplinary study. All space and furniture are configured and used in ways that best support the instruction. When changes are desired, most of the areas are easily reconfigured. Simple audiovisual equipment of various kinds is available, although more is needed. Some of the visual aids are student made; all of the A-V aids are used by students in ways they find helpful. In this varied program students plan their studies through conferences with the teachers. Much of the work proceeds independently, with some students conducting studies at home or on the Mankato campus. Students of varying ages work together as interests and program require. Older students frequently assist younger students, and occasionally the reverse happens. In short, the director and his colleagues have created a school where people of various ages can work and learn together. Their successes should serve to encourage others who share their commitment to making school an exciting experience.

2.8 View of science area at Wilson School.

Self-Appraisal

Following is a self-appraisal procedure for school personnel involved in planning new or remodeled facilities. After staff members have studied this report, each person should appraise the existing facilities and program. Copies of the evolving patterns figure (**2.1**) could be provided, with staff members indicating present status by noting positions for their school on each pattern. These individual assessments could serve as a basis for discussions with staff, administrators, and / or architects. As plans for new construction are reviewed, each staff member might be asked to project how the patterns for facilities and program might be changed. Areas of agreement or disagreement should be noted. We found in our study that substantial consensus can arise among teachers and administrators when crucial features are carefully analyzed.

If time and resources permit, visits by planning team members to selected schools can be valuable. The evolving patterns should be useful in systematizing observations in school visits. Other issues raised in Part 2 should be discussed with teachers during school visits or with architects in planning sessions. When two or more teachers visit the same school, their independent assessments in terms of the evolving patterns may serve as a good format for reporting to colleagues. Finally, limitations or deficiencies in the patterns should be noted.


facilities
interdisciplinary open space systems for learning materials
flexible laboratory study space, carrel units, carpeting
lab islands, movable benches
preparation and storage room for individualized packets
flexible lab-discussion space project areas, plant and animal rooms
integrated lab-lecture-discussion with tables and lab benches
massive fixed furniture; separate lecture, discussion, and laboratory rooms; wall cabinets; equipment storage for group work on common experiments
evolving pattern
technology
instructional technology for student planned individual and small group work
learning resource center with a-v and reference material
self-paced study materials 8 mm loop film, filmstrip viewers
dial-access tv and audio tape
computer assistance
closed-circuit tv
overhead projector
16 mm film wall charts, maps, backboards chalkboard
evolving pattern
program
integrated science heterogeneous age grouping
student planned learning activities
criterion referenced
study units individually paced, single discipline, single age group
norm referenced
alternate experiments special readings
study unit packages group schedule
extra credit or honors work
tracking, programs for high and low achievers
single subject, text-lab program group paced, group exams
evolving pattern
student-staff
student-staff planning of achievement goals integration of science study with other student interests
student centered learning activities, modules peer assistance
differentiated staff, technical support staff
team teaching, some student aides
text-lab guide but student planning for projects
student selection of optional activities
performance standards fixed by the teacher
teacher determination of curriculum
evolving pattern

Design Considerations for Secondary Schools

Part

2

Introduction

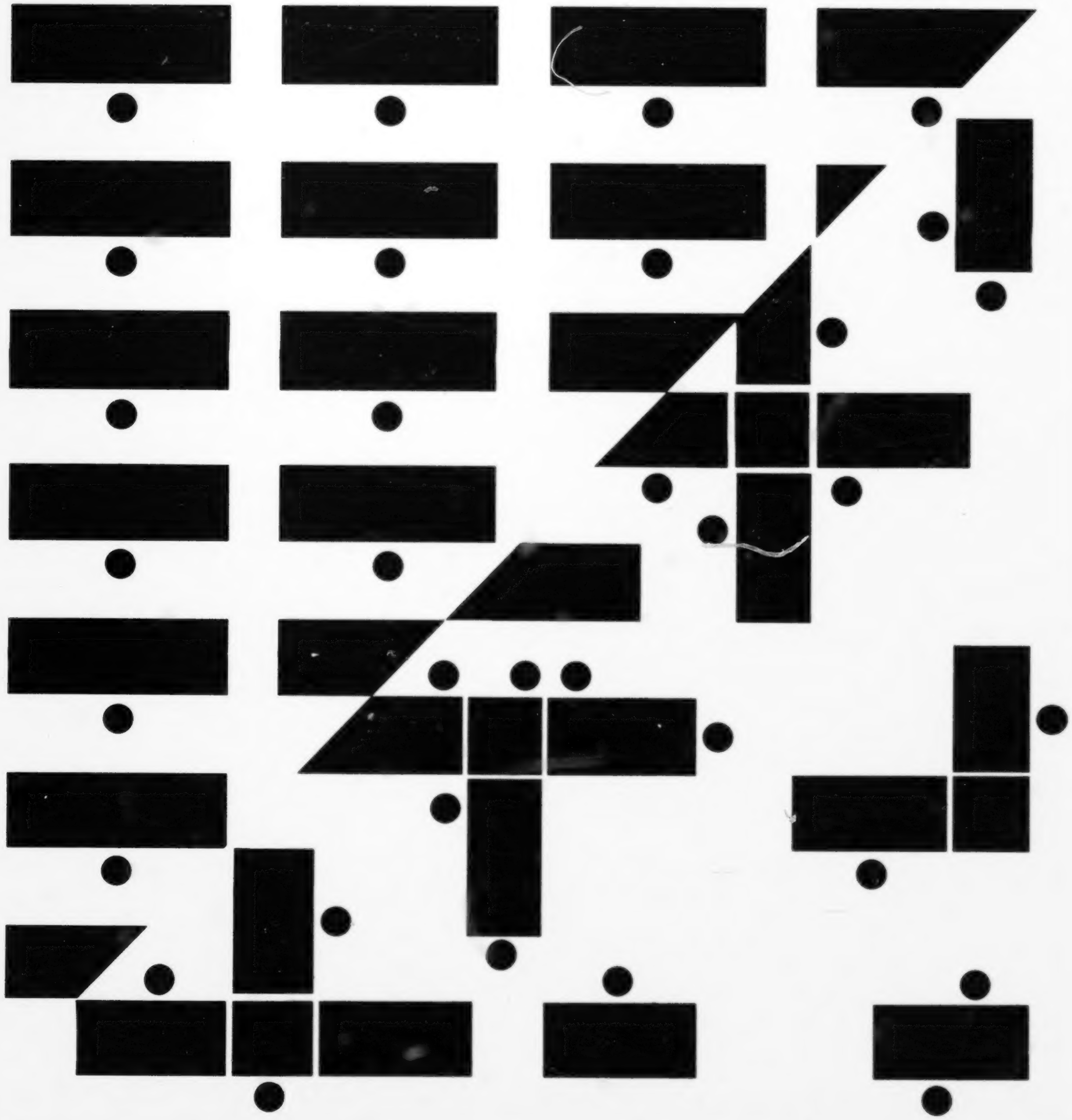
In Part 1 of this report we presented general concepts that need to be considered before planning new or remodeled science facilities. Part 2 illustrates a variety of facilities visited and presents what we view as important design considerations for new or remodeled facilities. This section of the report has been organized to complement and to coordinate with the concepts presented in Part 1. We see the concepts as contributing importantly to the orientation of architects and serving as a base for communication between school staff members and the architects.

Part 2 presents a wide range of detailed alternatives for varied aspects of school design. Wherever possible we have attempted some evaluation of alternatives, either in terms of economic feasibility or with respect to the way in which the alternatives contribute to the educational goals described in Part 1.

We suggest frequent reference to the information as preliminary drawings for construction are prepared, as construction plans are completed, and later as equipment purchases are planned.

Because building codes are so diverse and the details of construction are so varied, most of the minute considerations in building design must be left in the hands of architects. However, an architect needs guidance in relation to the overall purposes that the construction is to serve and the educational objectives that are to be implemented within it.

Chapter 3



Instructional Space

Traditionally, the instructional space required for science has been a lecture-discussion area and a laboratory with some type of laboratory benches bolted to the floor. During the 1920s and 1930s it was common practice to build the lecture-discussion area separate from the laboratory area. Frequently it was equipped with tiers of seats resembling a miniature auditorium. In schools with this arrangement, laboratory periods were often scheduled separate from lecture-discussion periods, with only one of the facilities available on any given day for a particular class. This arrangement represents an almost impossible scheme in terms of flexibility in instruction. In our study we still found some new science facilities with massive, fixed laboratory units. These are designed for a specific science subject and are located apart from other facilities.

More commonly, however, we observed science rooms designed for a combination of laboratory and discussion activities. In many schools, science facilities provide for seminar work, special project activity, and individual study utilizing instructional technology. In addition, a library or learning center may also be used by science students, sometimes during scheduled science periods.

A general consideration in planning the science space is its location with respect to the other areas in the school.

In *Designs for Science Facilities* [9] a Minnesota group recommended that science facilities be located close to other academic areas that emphasize an inquiry approach. The Minnesota group suggested proximity to social science areas rather than the traditional proximity to mathematics or industrial arts sections. We see no reason to recommend a preference for one or the other of these neighbors. The important consideration is that the science facilities be in contact with other learning areas of the school, for there is an evident trend toward increasing cooperation among science teachers and teachers in other academic areas. In a few schools visited, some interdisciplinary study is already in progress. We expect that as student schedules become more flexible and determined more by the individual, the natural evolutionary path of programs will be toward increased integration. Therefore, the science facilities and other academic areas should be planned for close cooperation and for possible interdisciplinary programs.

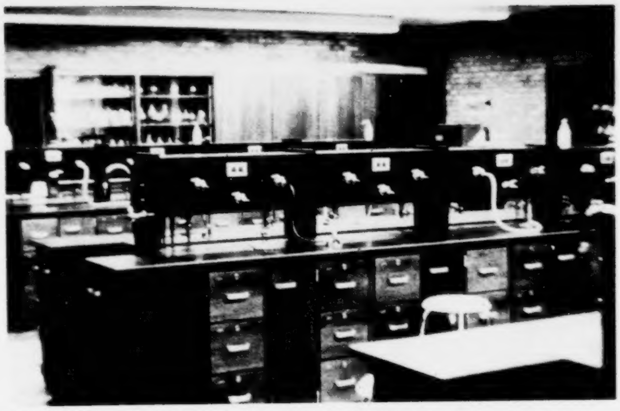
We urge consideration of other alternatives to the wall changes. These alternatives might include arrangements that do not use walls or partitions for dividing instructional space. Various kinds of movable cabinets, chalkboards, and other furnishings can be used to divide space and can be moved by teachers and students in a matter of minutes. Our concept of flexibility favors those arrangements that permit the use of any instructional space for almost any kind of science instruction through simple changes made by teachers or students.

Many new schools have also included arrangements for natural outdoor areas on the school grounds. Easy access to the natural area can be an important aspect of plans for the science facility. Such an area and access to it can also be important for art classes, social science classes, or other school programs.

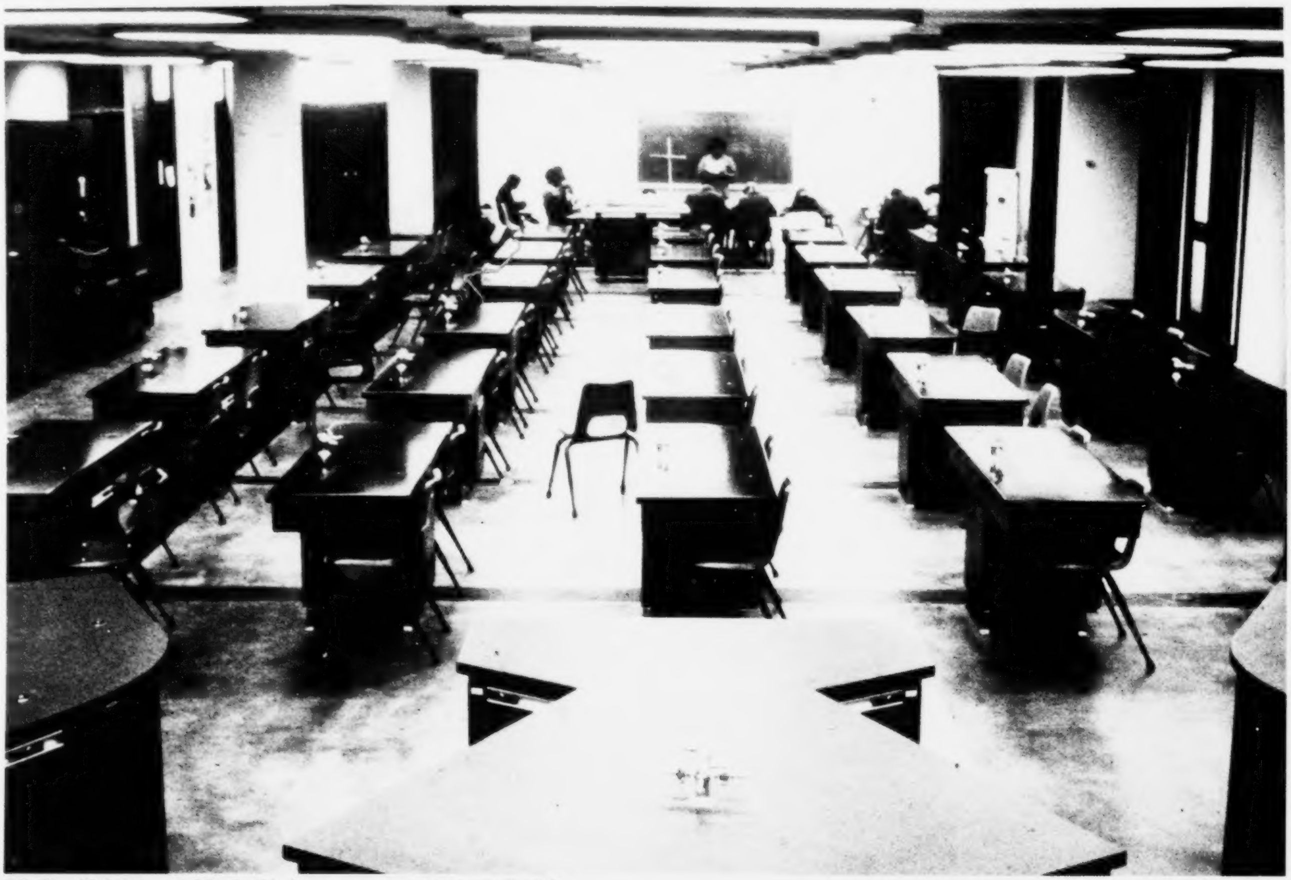
Throughout this report, we are emphasizing the need for **flexibility.** Within the instructional space, structural design contributes to flexibility. An instructional area is not flexible if changes in the space configuration, that is, rearrangement of walls, require special crews operating during vacation periods. Most types of wall construction that are presumed to provide flexibility do require special service when changes are to be made. Cement block walls cost only about one third as much as many types of portable walls and frequently are no greater deterrent to modification of space than are various kinds of demountable partitions. Except when the walls provide structural support, they can be removed by construction crews.

Laboratory Space

Our study team was surprised to see many new science facilities equipped with immovable furniture. Figure **3.1** shows an installation for a chemistry class in a new science building.[1] The furnishings shown preclude any possible rearrangement of this area for purposes other than traditional laboratory experimentation. Storage facilities are also arranged for group instruction in which all students proceed at the same rate on the same set of experiments. Figure **3.2** shows a new laboratory facility designed for use by all science classes in the high school, but with some striking oversights. Sinks were not provided in the large laboratory benches nor in the smaller, fixed laboratory units. Consequently, this space is difficult to use for many kinds of laboratory activities. Obviously, too, it does not lend itself to lecture-discussion or small-group work.



3.1 Massive, fixed laboratory furniture limits the uses for a given space.



3.2 Fixed laboratory tables in this large open room severely limit the kinds of activities that can take place here. Water supply and sinks were not provided in the lab benches.

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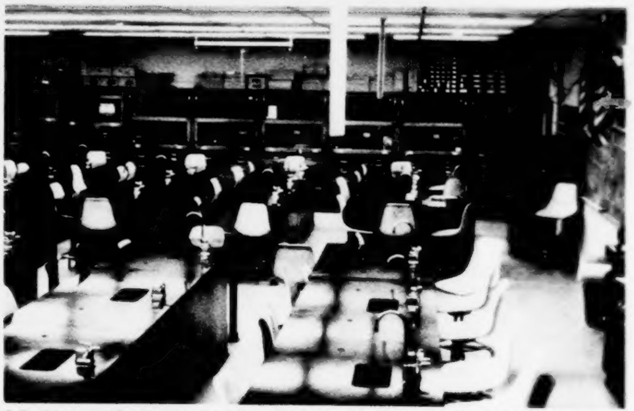
[1] Since similar examples might be found in other schools, names are not given of schools in which we saw examples of facilities or practices not recommended.

Figure **3.3** shows another arrangement of fixed laboratory furniture, but the laboratory space can be used for a wide range of integrated science activities. Here, supplies for students are distributed from a central storage area.

We would not recommend any of the configurations shown in Figures **3.1-3.3.**

All of these designs have limitations that are not necessary with conventional furnishings and alternative arrangements. However, the arrangement shown in Figures **3.3** and **3.4** does permit integrated, individualized science instruction and the employment of team teaching, technical support, and other support staff. It offers the most potential of the fixed-furniture-type laboratories illustrated.



3.3 A large laboratory used for all science subjects with limited flexibility in the use of any given space.

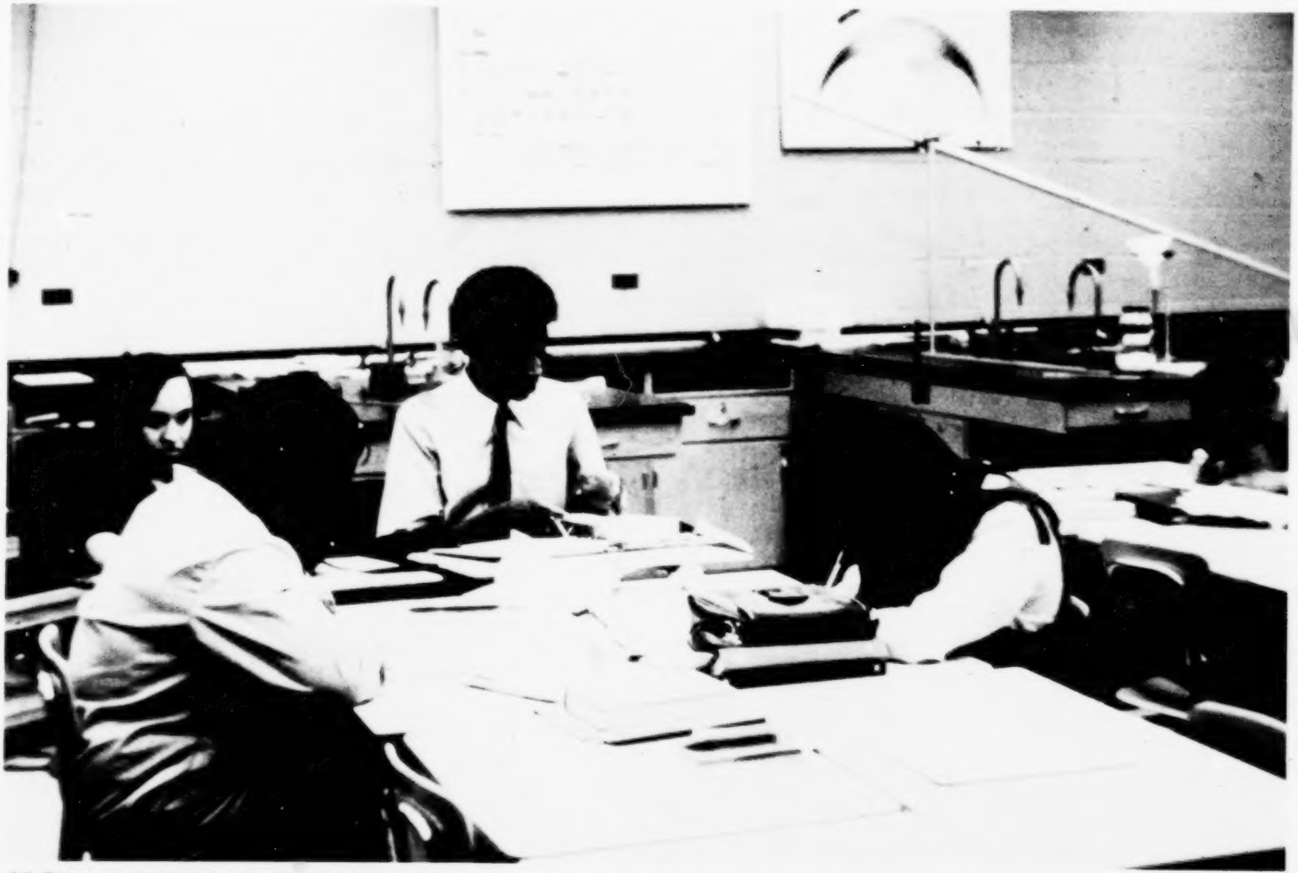
3.4 Students working in the facility shown in 3.3.

Laboratory Space

More commonly, we observed laboratories of the type shown in Figures **3.5-3.10.** Figure **3.5** shows a biology laboratory with tables that can be moved, although they are fairly massive. This kind of furnishing is used for combinations of laboratory work and lecture-discussion activity. Figure **3.6** shows a similar arrangement at another school. Figure **3.7** illustrates a peripheral arrangement of laboratory furniture with a central area for tables. The laboratories in Figures **3.6** and **3.7** are used in conjunction with learning centers where individual study can take place. Students can work either in the laboratory areas shown or in individual study areas.

3.5 A typical laboratory-discussion room used for instruction. Although tables are movable, the facility has limited flexibility and is designed for groups of 25 to 30 students. Brighton High School.

3.6 Laboratory-discussion room used in conjunction with other facilities for individualized study. Monona Grove High School.

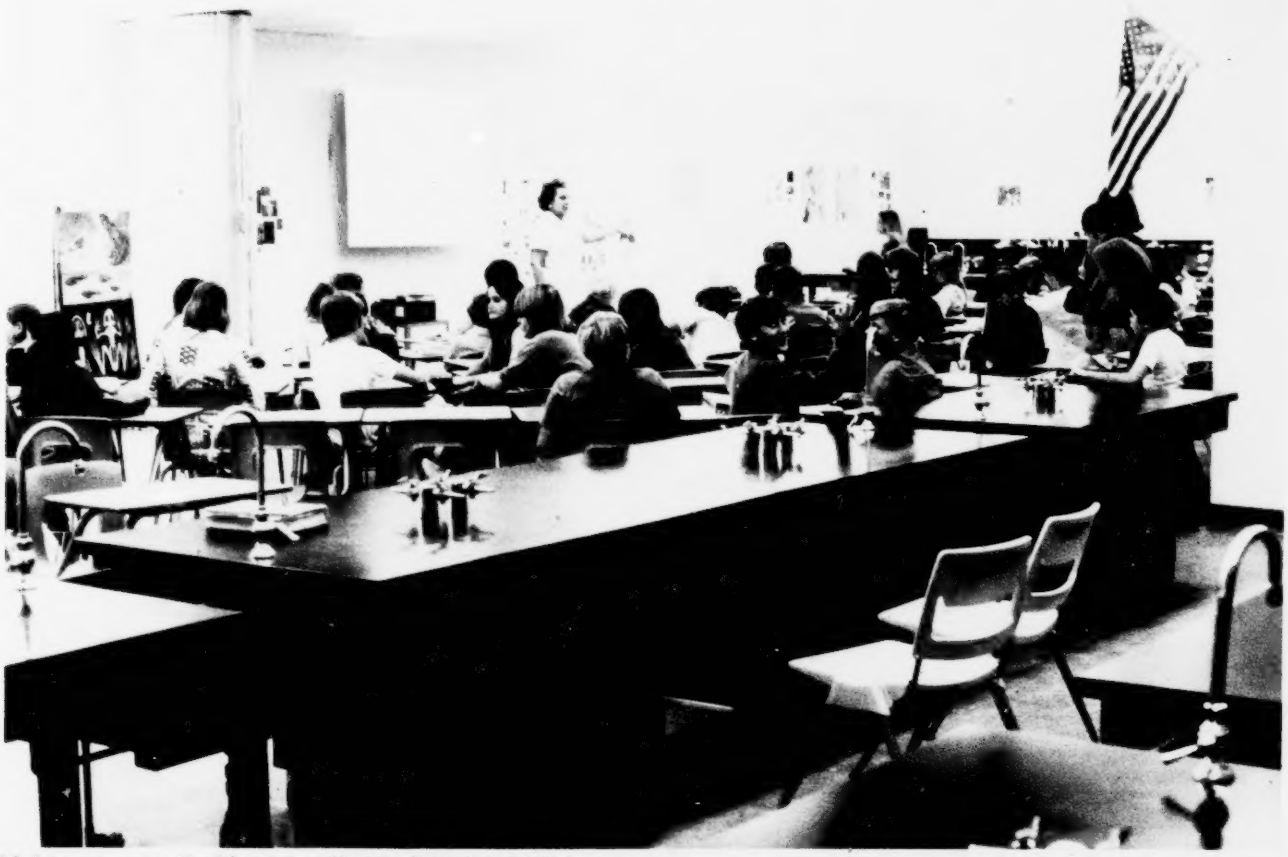


3.7 This room with peripheral laboratory benches allows for a variety of activities in the central area. Coatesville Area Senior High School.

Laboratory Space

Figure **3.8** shows a large laboratory and discussion area in a junior high school. Although laboratory furniture is fixed around the periphery of the room, there is a large open area in which various kinds of instruction can take place. The high school laboratory in **3.6** has massive fixed laboratory units but also space for individual or small-group study. This configuration allows for a variety of learning activities. However, the massive laboratory units are of minimal value for experimental work and severely limit flexibility in the use of this space.

There are no fixed walls between the science areas shown in **3.9** and similar areas for other science studies. Figure **3.10** shows another arrangement of laboratory units with contiguous discussion space. This laboratory is used for chemistry and other sciences and is entirely carpeted.



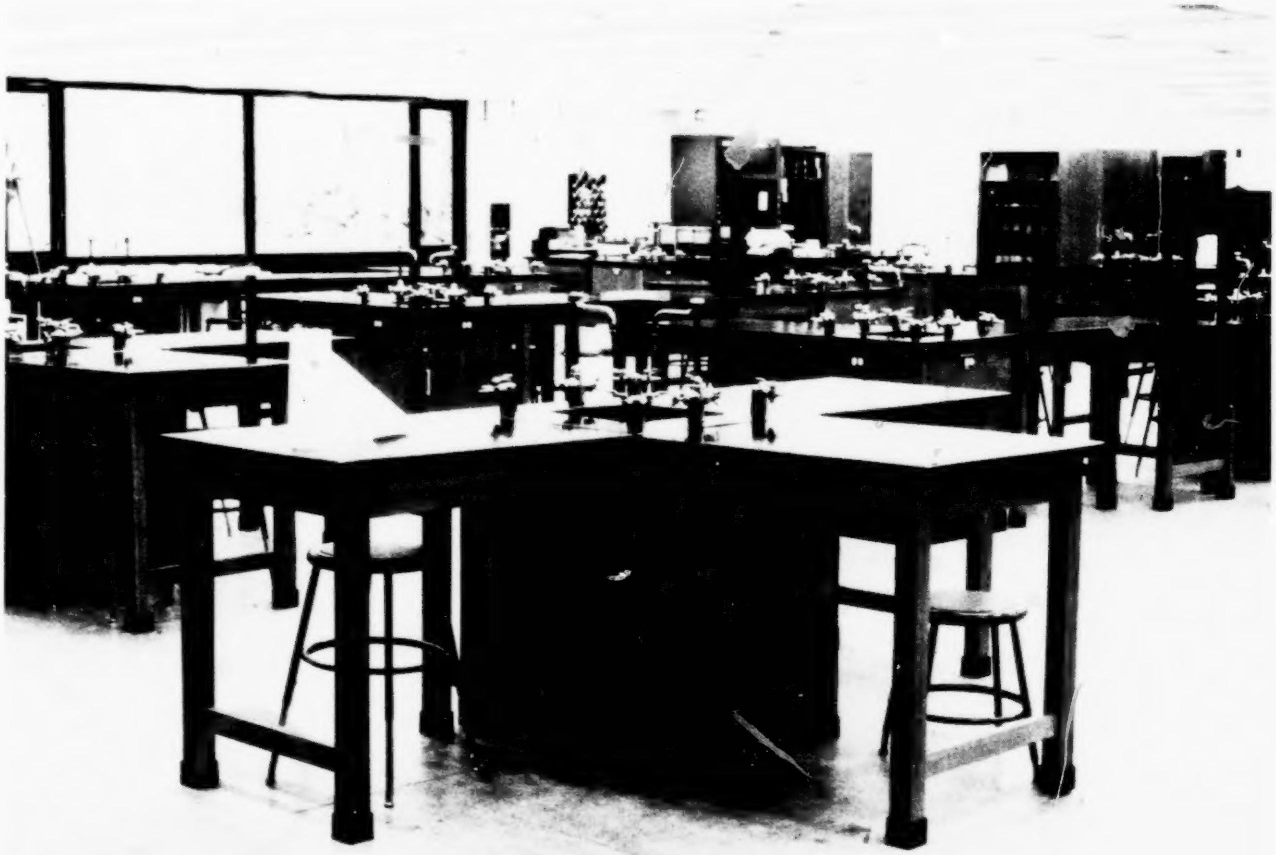
3.8 A large room used for laboratory and lecture-discussion work in a junior high school. Boca Raton Junior High.

3.10 A carpeted area used for chemistry in an open science facility. Little Falls Central School.

3.9 Large fixed laboratory tables and areas for individual student work. These laboratory benches restrict the flexibility of this facility.

Laboratory Space

By far the most flexible laboratory furnishings are the lab island configurations. The table arrangements in Figure **3.11** show one type of laboratory island. Figure **3.12** shows an island arrangement in a new high school. Tables that are adjustable in height are shown in Figure **3.13.**



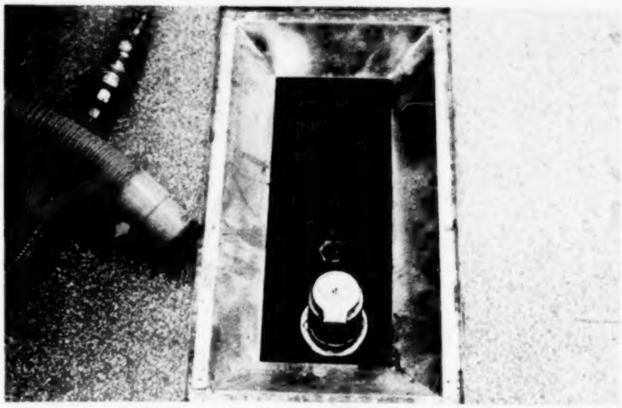
3.12 An open laboratory used for all sciences with lab islands and movable tables. University High School.

3.11 Laboratory islands and work tables used with more traditional peripheral lab benches and wall cabinets.

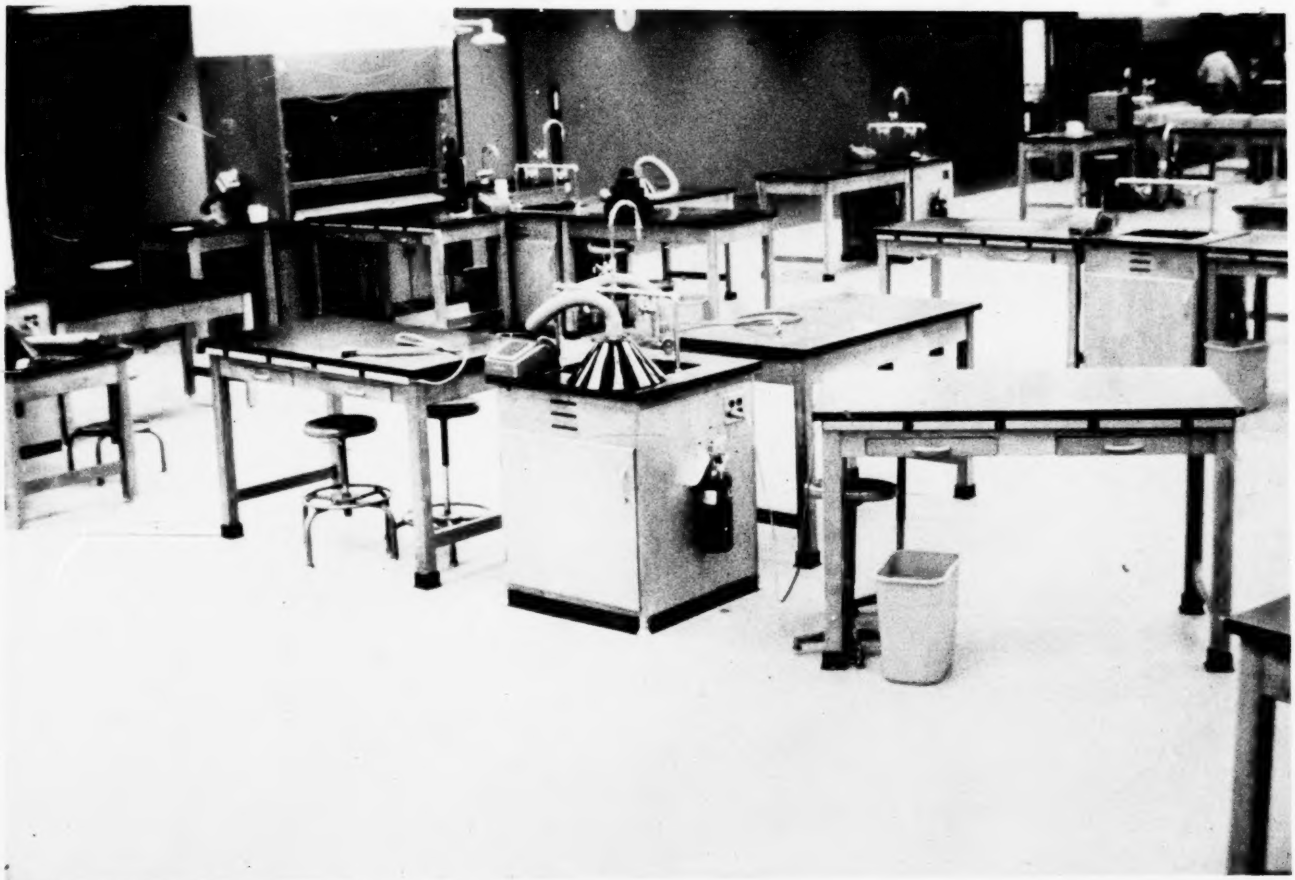
3.13 Laboratory islands used with lightweight tables that are adjustable in height. Thomas Jefferson Senior High School.

Laboratory Space

The utilization of the laboratory island concept was found at St. Andrews College. Although this is a college facility, it could serve equally well for a secondary school. Figure **3.14** shows one of the laboratory islands and a chemical hood and safety shower against the wall; Figure **3.15,** an arrangement of tables around a laboratory island. The flexibility with which these furnishings can be used allows for almost any option of laboratory or individual project activity. The laboratory islands at St. Andrews College can be completely detached in minutes. Figures **3.16** and **3.17** show the plug-in attachments for this facility.

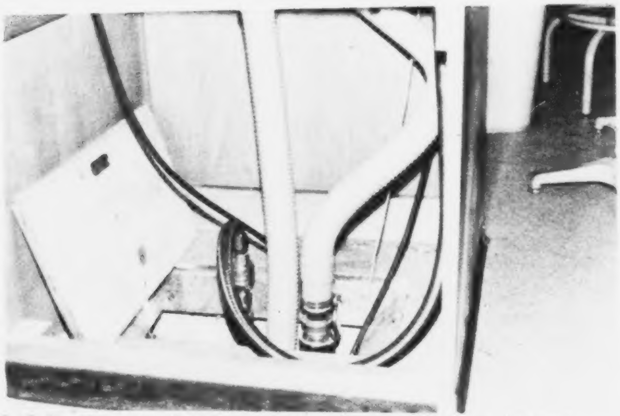


3.16 A floor well for a laboratory island showing connections for vacuum and water lines. St. Andrews Presbyterian College.



3.14 Laboratory islands in a large open laboratory. These island units can be unplugged and moved. They contain water, electricity, vacuum line, and intercom units. St. Andrews Presbyterian College.

The laboratory island type of furnishing, together with central storage of material for experimentation and study, allows great flexibility in the use of laboratory space. Moreover, this space can be used for any science subject area or indeed for a number of other kinds of learning activities. If facilities for extensive experimentation are desired, we strongly recommend the laboratory island configuration together with appropriate laboratory tables and other furnishings. This arrangement also permits an optimal logistic system for equipment and materials as described in some detail in Chapter 5.



3.17 Plug-in connection for a movable laboratory island. St. Andrews Presbyterian College.

3.15 A laboratory island set-up for student project work in one corner of the laboratory shown in 3.14. St. Andrews Presbyterian College.

Lecture-Discussion Space

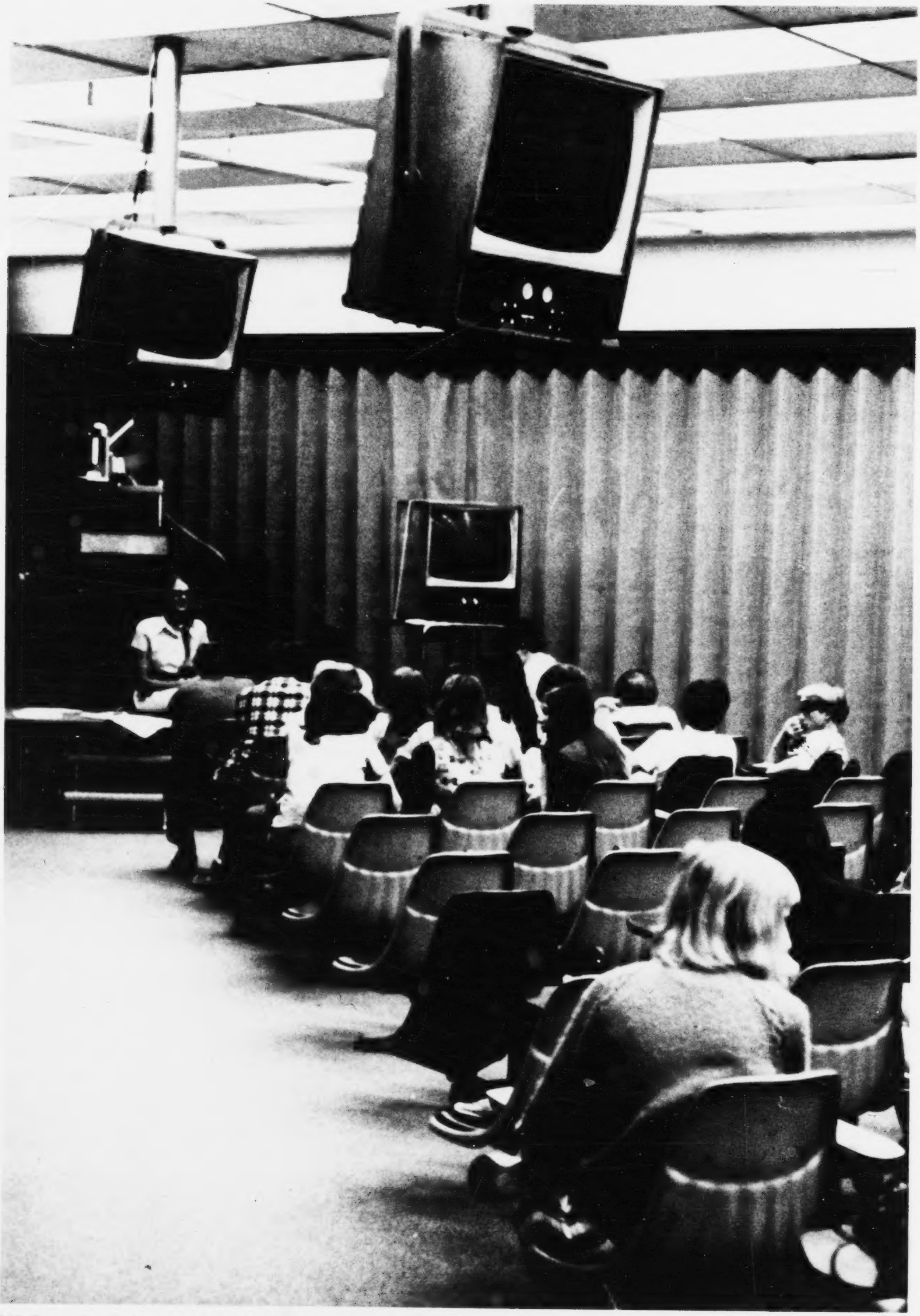
In the traditional style of teaching, lecture-discussion programs constituted a large portion of the program. As schools have moved to individualized instruction and to more opportunity for inquiry-oriented activities, the role of the lecture has declined and in some cases has been eliminated. Nevertheless, there are still occasions when it is useful to assemble students for some type of group presentation.

Figure **3.18** presents one of a series of pie-shaped lecture rooms separated by folding partitions. The partitions may be opened, creating a large assembly area. As with other assembly areas for multiple use, there are advantages and disadvantages to this space. One disadvantage is that folding walls do not completely isolate the areas, especially when audiovisual aids are being employed.

Because most schools will have some form of general assembly area, a large lecture facility exclusively for science cannot be recommended. In schools with enrollments of 1,000 or more, there is value for an assembly room that will seat 100 or 150 students, but usually this kind of facility can be shared by science and other academic areas.

Figure **3.19** shows a school auditorium that can be divided into four sections. The large forward section seats several hundred students. The rear section is divided by partitions into three areas, each of which seats more than one hundred students. In principle, three different lecture groups could meet in the rear of this school auditorium. In practice, teachers have found unacceptable levels of interference between groups if more than one area are being used. Consequently, this space is relatively inefficiently used for instruction and is only occasionally used for large student assemblies.

3.19 A large auditorium with three divided sections at the rear. Simultaneous use of large group areas in the rear for different courses has proved unfeasible. Little Falls Central School.

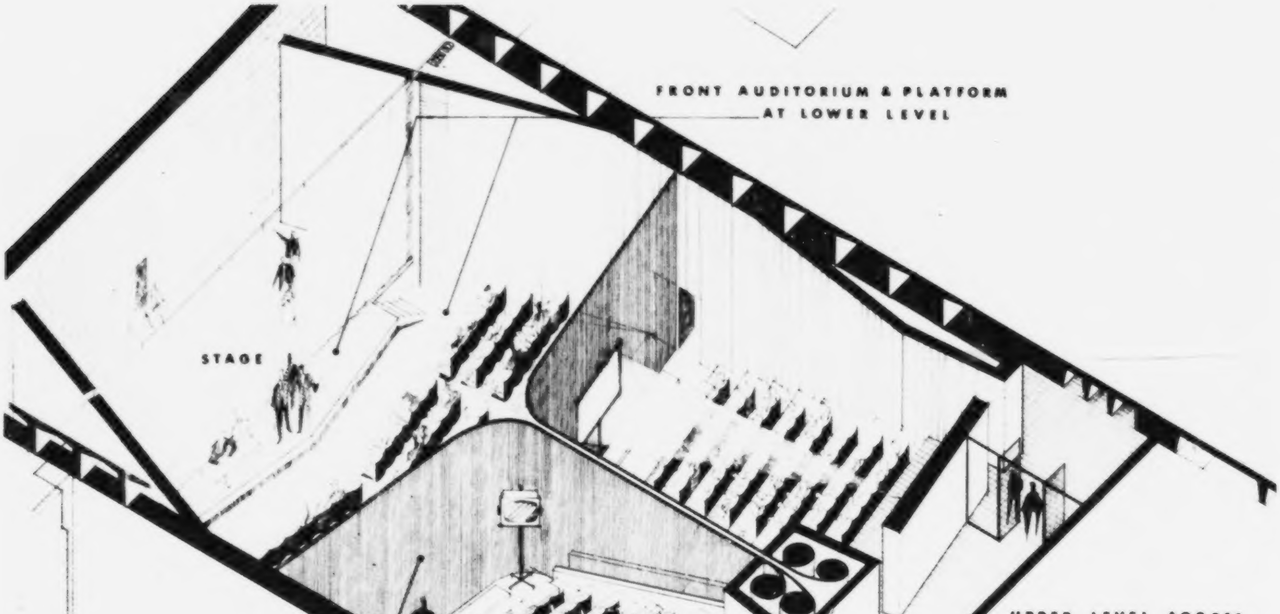


3.18 One section of a large area divided by folding walls. Closed-circuit television is available but seldom used for science instruction. Adams Central High School.

Lecture-Discussion Space

New design methods now permit construction of divided auditoriums that provide sound isolation of sections. The double wall movable partitions of the auditorium in **3.19 A** provide excellent acoustical separation between sections and easy conversion to a large lecture room or theatre.

3.19 A and B The double operable walls dividing this large auditorium provide excellent acoustical separation between sections (photo credit: Phokion karas)


FRONT AUDITORIUM & PLATFORM AT LOWER LEVEL
STAGE
UPPER LEVEL ACCESS TO LECTURE ROOMS
OPERABLE WALLS

3.19 B

Lecture-Discussion Space

A traditional lecture-demonstration room is shown in Figure **3.20.** Figure **3.21** is a more common type of lecture facility. Seating 120 students, this room provides space for presentations to combined classes of students or for special events, such as special films, or programs by visiting lecturers. Televised presentations are occasionally used in this school. Figure **3.22** shows a similar room being used for group testing. As long as group tests of one kind or another are given, rooms such as this prove useful for administration of tests. As schools move increasingly to individualized instruction, with criterion-referenced evaluation, this use for lecture rooms is eliminated.

3.22 A lecture discussion auditorium can also serve as a place for large-group examinations.

3.20 A traditional lecture-demonstration room typically used for group instruction where lecture and laboratory work are rigidly scheduled.

3.21 A large lecture hall used for group instruction. This kind of facility became popular with the emphasis on team teaching in the 1950s.

Small lecture rooms are found in some newer schools. Figure **3.23** shows a small lecture-demonstration-discussion room. This room is used in conjunction with a large open laboratory and an individualized program that includes modular scheduling. Students schedule a 20-minute lecture-discussion session at least once per week, depending on the science program they are pursuing.

In general, however, we find little value in the large lecture-discussion areas shown in Figures **3.18-3.23.** Most of the activities conducted in these areas are inappropriate for individualized study. Where technological support is available, many forms of media-assisted instruction can be more effective than large-group work. Schools that have large multiuse areas, which may include laboratory work as well as lecture and discussion activities, have not found a need for any lecture space devoted exclusively to science. When large, well-equipped learning centers are available in the schools, the flexibility sometimes needed for scheduling laboratory space can be accommodated through extensive use of space in the general learning center.

3.23 A small lecture-discussion room used in conjunction with a large open laboratory. Nova High School.

Individual and Small-Group Study Areas

One of the most conspicuous trends we observed in our visits involves a variety of approaches to provide instruction to individuals or small groups of students. In the traditional facility, these efforts sometimes take place in the corner of a lecture room, as shown in Figure **3.24.** Although this is hardly an ideal facility, the conscientious teacher can work with individuals or small groups of students in a variety of patterns. For example, Figure **3.25** shows a teacher working with an individual student at the back of a laboratory room. In Figure **3.26** we see a teacher assisting a student in a study carrel in the science learning center.

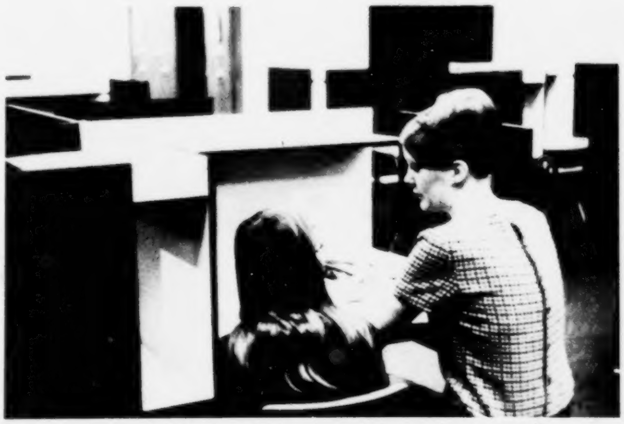
3.24 A small discussion group in the corner of a lecture room. Since adequate space is not available for the extensive small-group discussion used in this school, the old lecture facility must suffice. Monona Grove High School.

mouse→Hawk
bacteria

3.25 Teacher and student discussing laboratory work in a conventional laboratory facility. South Glens Falls Central School.

Individual or small-group work could also take place in the general learning centers of the school. Figure **3.27** shows a group of students discussing their work in a casual group at a bookcase. In Figure **3.28** students mix pleasure with work in this attractive, carpeted student center.

3.28 A carpeted informal study lounge for work or casual conversation. Adams Central High School.



3.26 Teacher and student conferring in a study carrel in a room for individualized science study. Monona Grove High School.

3.27 Students discussing work in a general learning area. Oak Grove High School.

Individual and Small-Group Study Areas

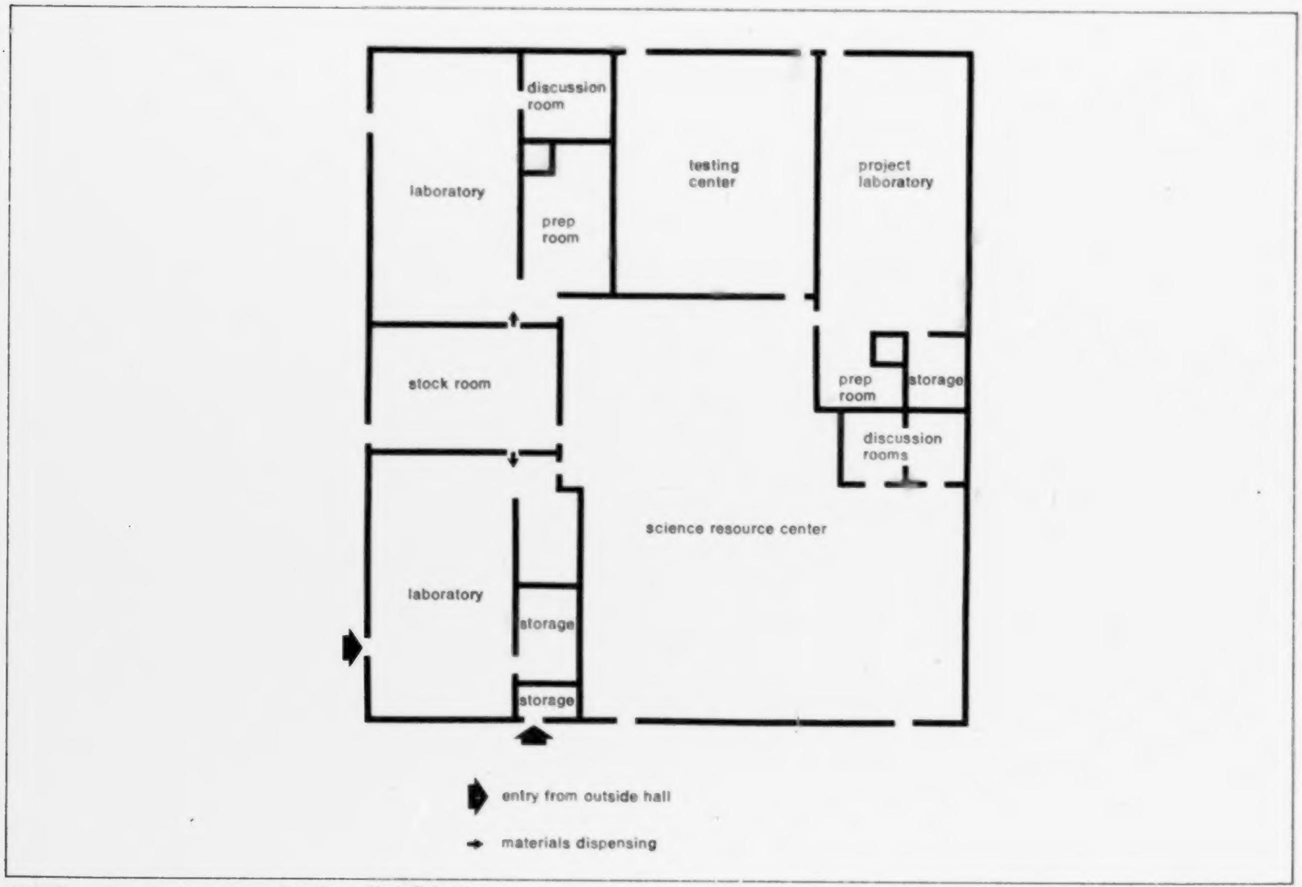
When new facilities are being planned, it is frequently useful to arrange for some type of small-group seminar or independent study areas. Such an area is shown in Figure **3.29.** Another small seminar or discussion room is illustrated in **3.30.** In addition to such seminar or discussion areas, student project areas are also needed. These will be discussed later.

3.29 A quiet study area adjacent to the science laboratory. Cloverleaf Junior High School.

3.30 A small room used for conferences and project work, adjacent to a large science laboratory.

It is very desirable to have some kind of area where a teacher and a student can discuss problems openly and frankly. Occasionally such space is provided in the faculty office area, but usually students are reluctant to invade this territory. The small room shown in Figure **3.31** is immediately adjacent to the science learning area as shown on the floor plan in Figure **3.32.** With space of this type in close proximity to other science teaching areas, the teacher and student can easily step away from a group for an informal discussion. One or two such areas adjacent to a science learning center for general purposes could be highly useful.

3.31 A small conference room and office adjacent to the science laboratory. Oak Grove High School.


discussion room
laboratory
prep room
testing center
project laboratory
stock room
prep room
storage
discussion rooms
science resource center
laboratory
storage
storage
entry from outside hall
materials dispensing

3.32 Floor plan of science area. Oak Grove High School.

Individual and Small-Group Study Areas

Private staff offices have advantages for student conferences and faculty study, but exchange between staff members may be curtailed. When staff are housed together in one area, there is more opportunity for dialogue, and when students are encouraged to see staff members in this area, excellent rapport between staff members and students may result. Although serious study or personal counseling may be restricted in a setting such as that shown in Figures **3.33** and **3.34,** improved interpersonal relations may be a compensating advantage.

It is difficult to arrange for the above-mentioned adequate individual or small-group working space when school programs are large-group oriented and scheduled. It is also difficult to have adequate space if both rigid laboratory installations and group-based science programs are employed. Moreover, resources are limited, and very few schools will find it possible to have facilities for traditional science instruction and also adequate space for various forms of individualized activity. We observed that traditional, inflexible science facilities were accompanied by group-scheduled science programs, with learning activities dominated by the teacher. There was an equally obvious link and complementary relationship between study areas for small groups and programs oriented toward individualized or small-group learning. Therefore, we recommend that schools clarify their program objectives before planning instructional space.

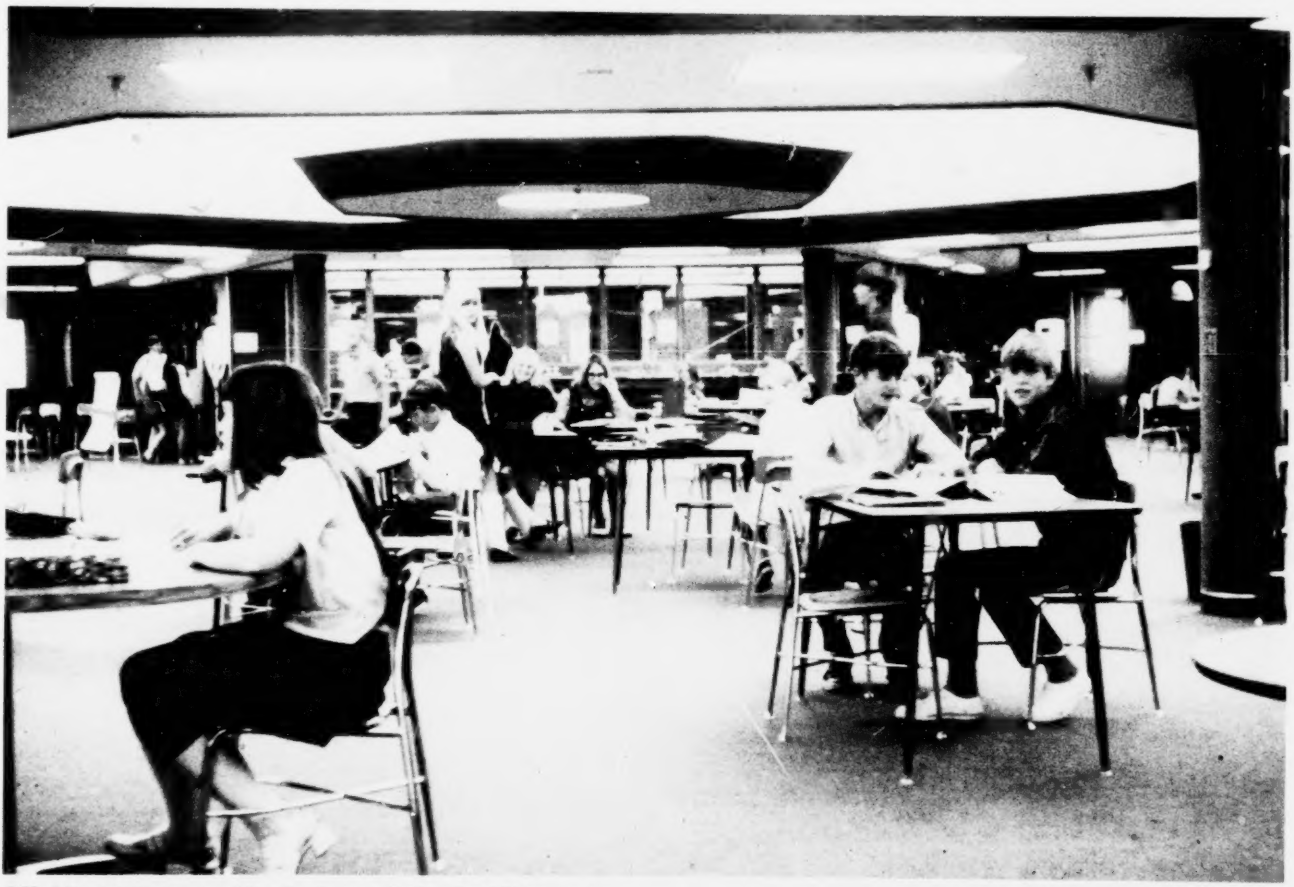
3.33 Science staff area used also for discussion with students. Thomas Jefferson Senior High School.

3.34 A science staff area and preparation room used by both students and staff. Oak Grove Junior High School.

Integrated Learning Areas

The instructional areas that best facilitate both a modern instructional program and humanistic relations among students and staff are those that employ extensive integrated activity areas for learning. We have already used the facilities shown in Figure **3.35** as an example of an outstanding facility. This large, carpeted junior high school facility allows for a variety of individual, small-group, or large-group activities. Students from grades seven, eight, and nine work together on schedules tailored to their individual rates of progress. Figure **3.36** shows a seventh-, an eighth-, and a ninth-grade girl working together on an experiment. The wide degree of flexibility provided in the program is very much enhanced by the flexibility available in this facility. The central storage area shown in the rear of Figure **3.35** facilitates dispensing a wide variety of materials for the students' use. This facility approximates an ideal instructional arrangement. If we were given free choice in modification, we would suggest islands with laboratory tables in a portion of the facility, rather than the laboratory benches provided on the periphery of the large, open room.

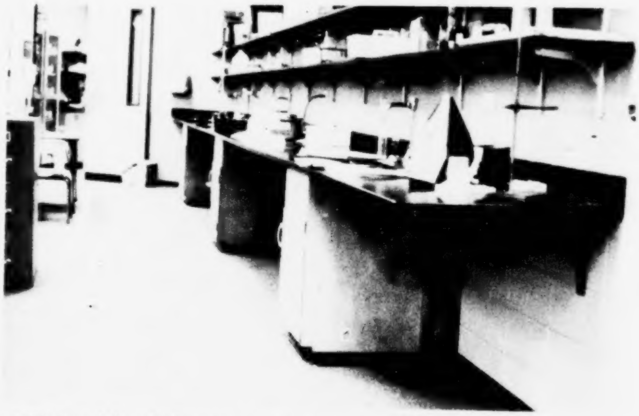
3.36 Seventh-, eighth-, and ninth-grade girls working together on a laboratory experiment. Sand Ridge Junior High School.



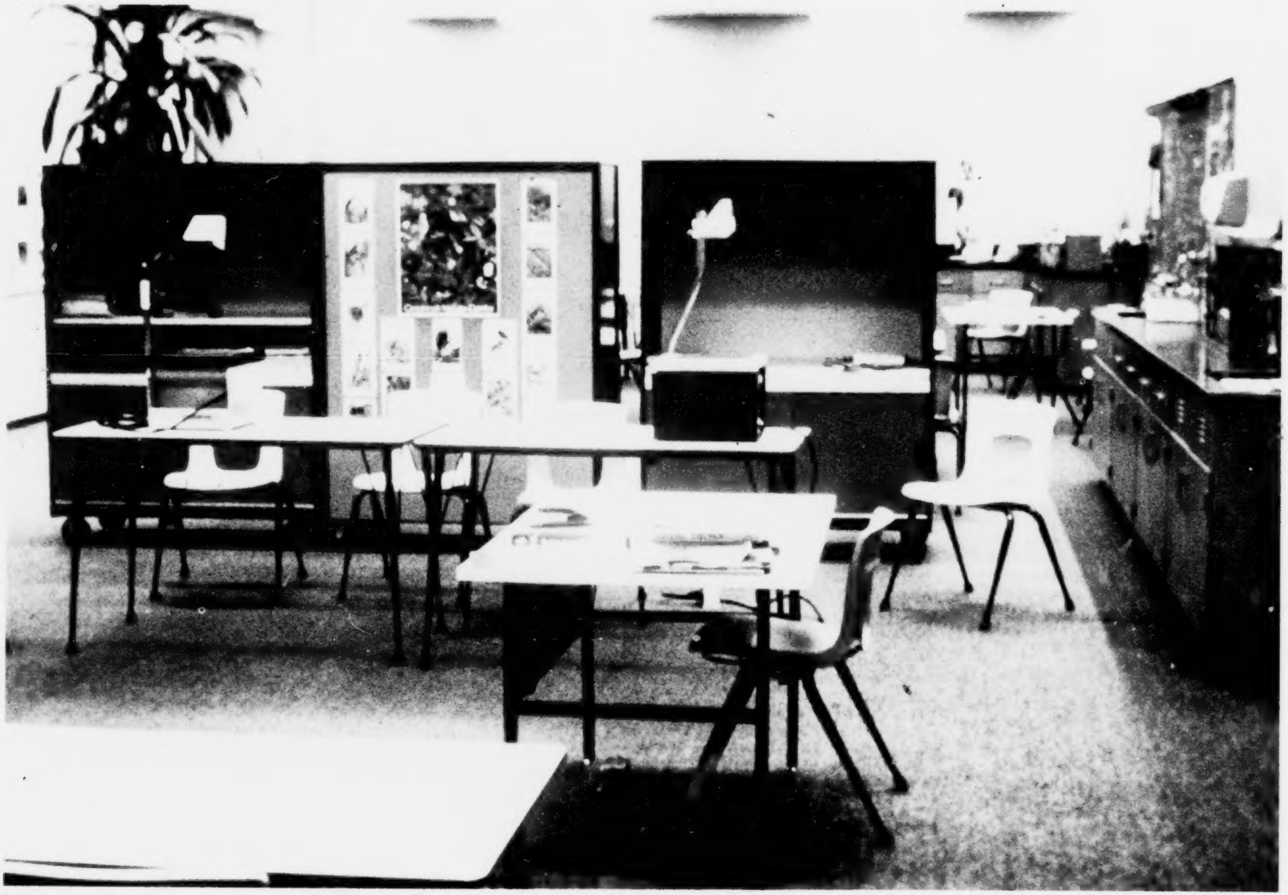
3.35 A large open area used for all science activities. Sand Ridge Junior High School.

Integrated Learning Areas

Figure **3.37** shows a peripheral laboratory facility adjacent to a large open science area. Figures **3.38** and **3.39** show additional views of this same open science facility and some laboratory furnishings, again located peripherally. This new school, carpeted throughout, allows for almost unlimited configurations of learning areas, with movable cabinets and other units used to separate instructional areas.

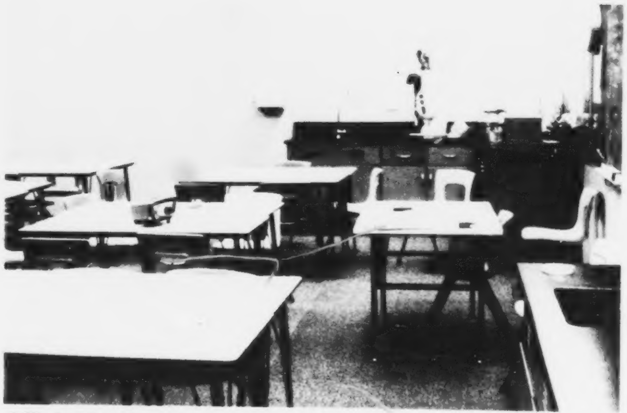


3.37 A peripheral laboratory arrangement in an open science learning facility. Mariemont High School.

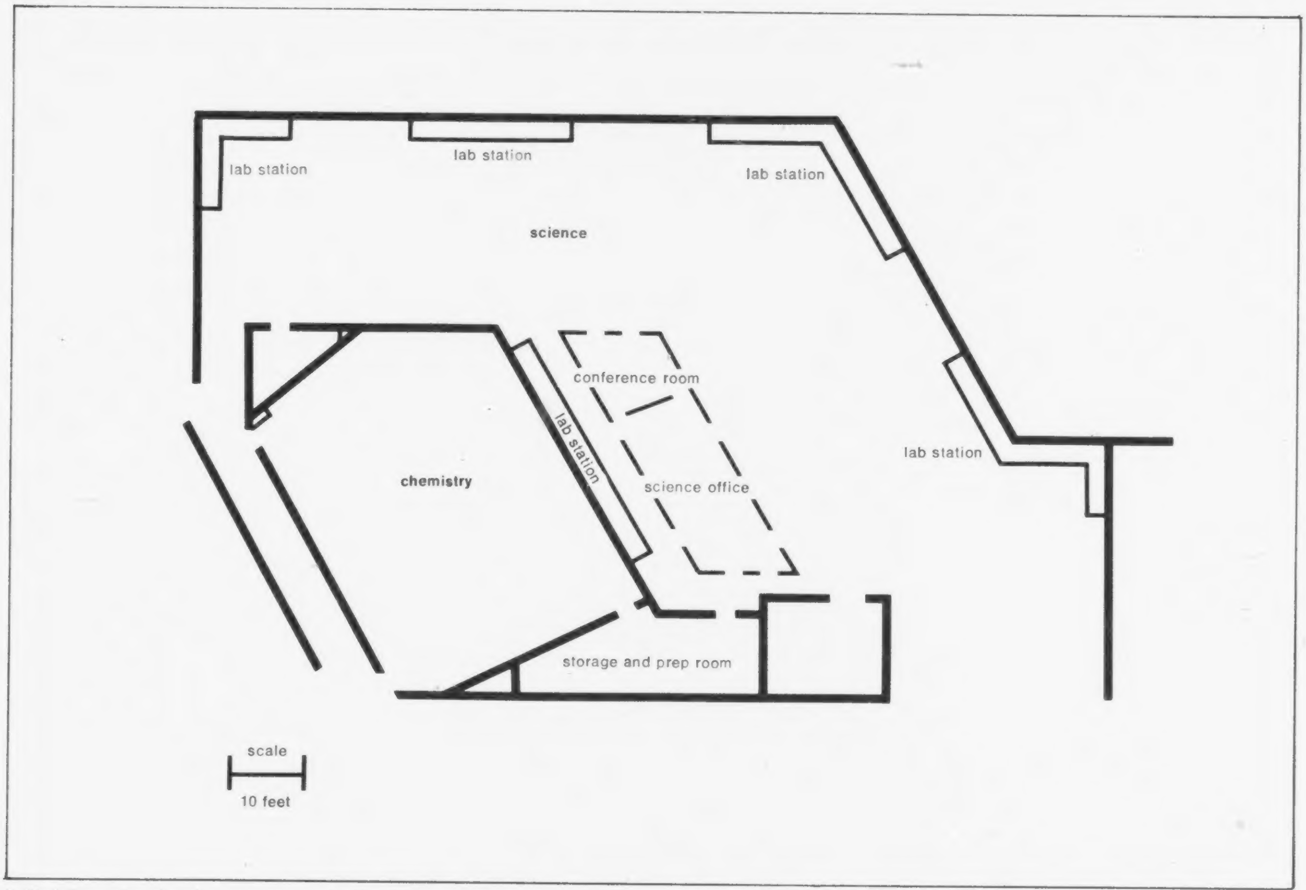


3.38 Laboratory-discussion areas in an open science facility. Rolling cabinets are used to divide space. This area is carpeted. Mariemont High School.

The facility in this school has a chemistry laboratory enclosed with block walls, but the teachers were unanimous in their dissatisfaction with the laboratory and in their belief that the chemistry program could have been conducted equally well in facilities similar to those shown in Figures **3.37, 3.38,** and **3.39.** This school, too, is close to ideal in terms of facilities, although laboratory furnishings are less than optimal. The use of laboratory islands would have permitted more adequate provision for laboratory work and considerably more flexibility in the use of the instructional space. A floor plan for the science area is shown in Figure **3.40.**



3.39 Another view of an open laboratory-discussion facility. Movable tables allow flexibility in study activities. Mariemont High School.



lab station
lab station
lab station
science
conference room
lab station
chemistry
science office
lab station
storage and prep room
scale
10 feet

3.40 A floor plan showing arrangement of facilities at Mariemont High School.

Integrated Learning Areas

The facilities shown in Figures **3.35-3.39** are in new schools. However, it is possible to create excellent integrated learning areas in old facilities. In Chapter 2 we described the modifications at Wilson School in Mankato, Minnesota. Figure **3.41** shows one of the areas where the variety of learning activities can take place in what once was a traditional science laboratory. Figure **3.42** shows a student in another school working on an experiment while classmates pursue other activities. This girl is working in the corner of a room that was used for a traditional science program a few years ago. An adjacent room has been modified for individualized study with technological assistance. This room also serves as an area where teachers can counsel students as questions arise. In Figure **3.43** a teacher discusses a problem with two students who have been engaged in individualized study in a carrel unit.

3.42 Students work individually or in small groups in this laboratory facility. Jamesville-Dewitt Central School.

3.41 An old science laboratory converted for multiple use in science. Wilson School.

3.43 A science teacher counsels two students working in an individualized study program. Jamesville-Dewitt Central School.

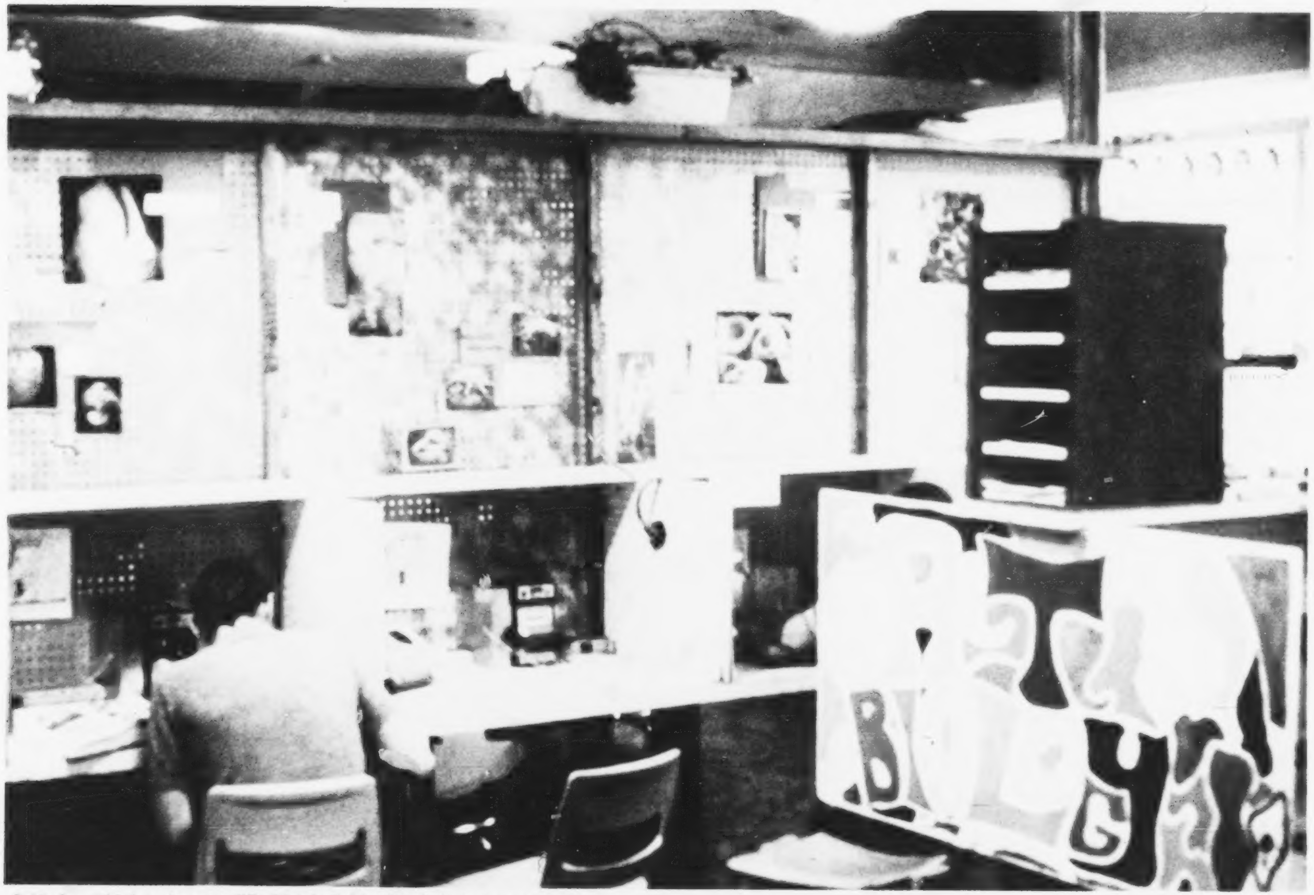
Integrated Learning Areas

In a Montana school, (Figure **3.44**) an ambitious teacher has modified his old science laboratory into a series of learning areas, including a number of audio-tutorial carrel units. Students can proceed in individualized study in the carrel units, or they may engage in other learning activities in this room. This colorful facility was built largely from pegboard and simple materials and can be easily reconfigured as the occasion demands.

There are other examples of integrated learning areas, but too often these tend to be used in traditional ways. Figure **3.45** shows a new facility in a school of open design that is used primarily for group instruction. Figure **3.46** shows a laboratory scene with adjacent independent-study area visible through the glass wall. While such a facility has the potential of being used for integrated learning, the rigid, fixed furniture and the expensive, unnecessary partitions encourage instructional practices along traditional lines.

From the standpoint of costs, integrated learning areas can be much less expensive to design and construct than are traditional patterns employing separate rooms for laboratories, discussions, and lectures.

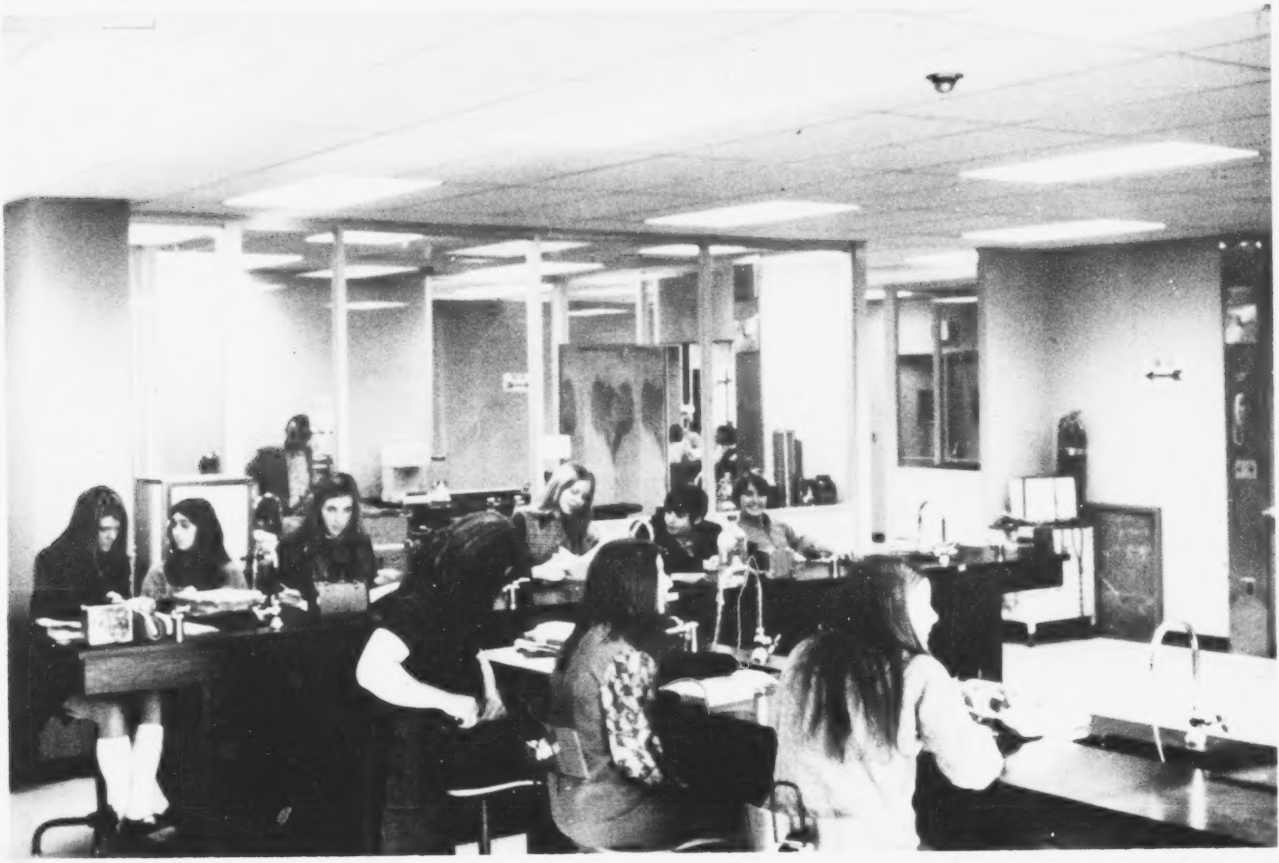
We are not advocating only large open areas, but are recommending that large open areas serve as the core of instructional facilities, with several kinds of smaller rooms adjacent to this area for individualized and small-group work. In addition, space needs to be provided for special activities such as project work. With a combination of large open areas and adjacent small rooms for special work, it is possible to achieve both economy and maximum potential for the instructional program in science.



3.44 An old laboratory modified for individualized study through the use of pegboard and other low-cost materials. Carrels for individualized study are available in the facility. Fort Benton High School.

EXIT
22.4 LITERS
ONE CUBIC FOOT

3.45 A science area in an open school can be used for lectures to groups of students. Little Falls Central School.

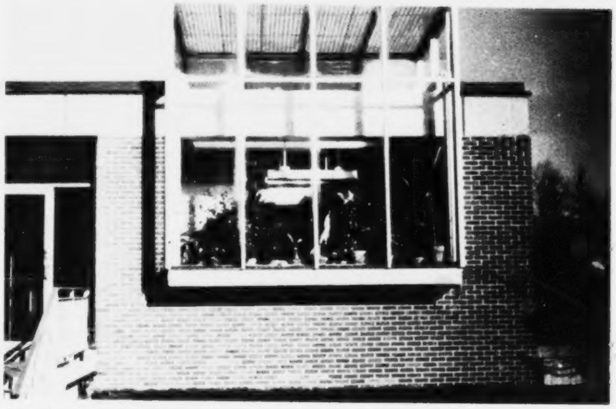


3.46 A science laboratory with individual study and project rooms behind glass partitions at the rear. Greenwich Senior High School.

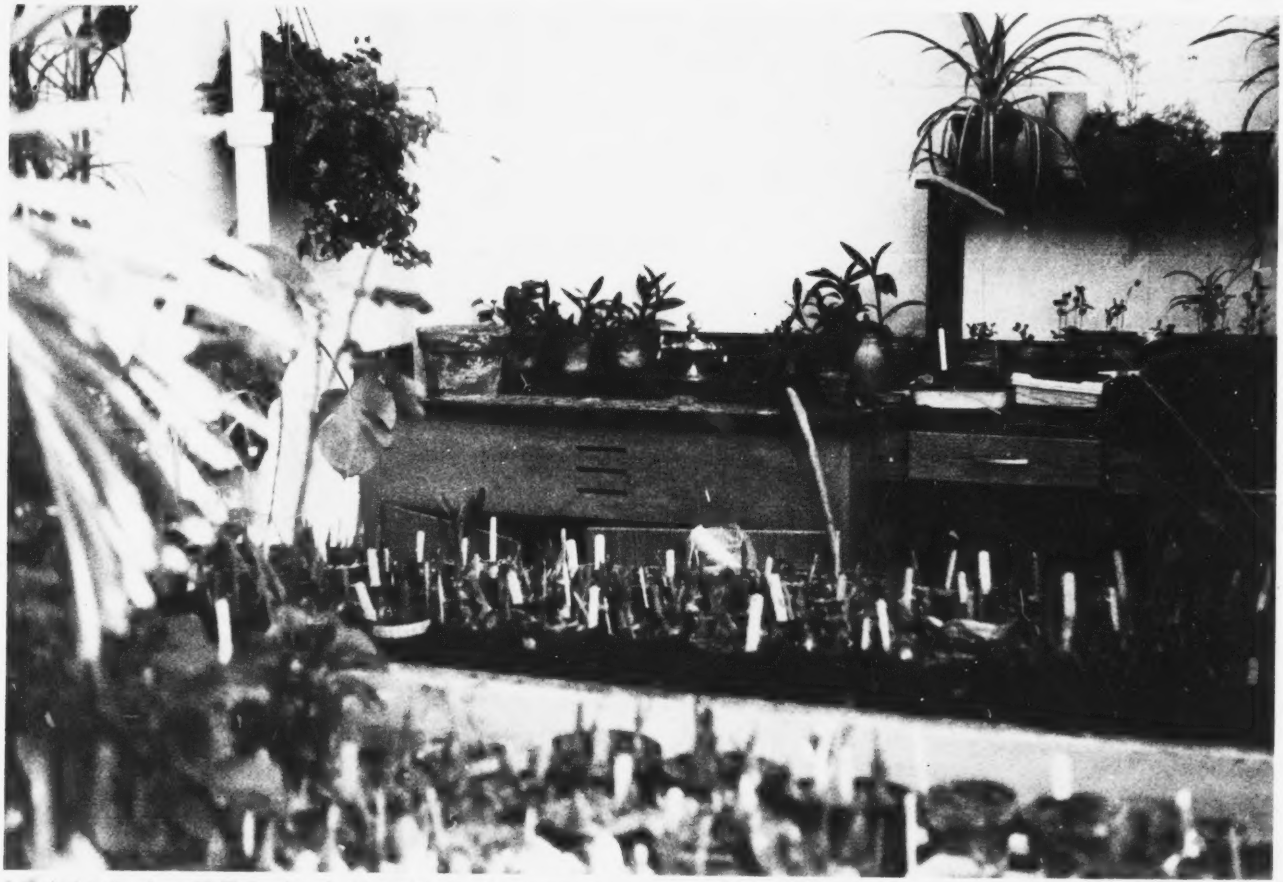
Areas for Special Projects and Special Purposes

In our description of evolving patterns, we have shown that arrangements for students' special project work may be found in a wide variety of programs and facilities. In general, special project work is limited to the most motivated students. However, in some smaller schools or private academies, project work can be available to all students, and is sometimes required for those students who wish to earn a higher grade. In individualized study programs, some provision for extended study of a special problem by one student or a small group of students is also needed. Usually it is not feasible to conduct these special project activities in regular classroom facilities, whatever their nature. Long-duration studies usually require some provision for security so that experiments will not be interrupted or delicate apparatus abused or damaged.

The greenhouse may be an ideal space for project study. Figures **3.47-3.50** show some examples of greenhouses. Unfortunately, greenhouses are sometimes located in areas of inadequate illumination or some distance from science facilities. All science facilities also need areas for growing plants as a source of materials for regular class study. For this purpose, the greenhouse usually proves unnecessarily difficult to maintain and often little but weeds and dried-up tomato plants can be found in greenhouses.

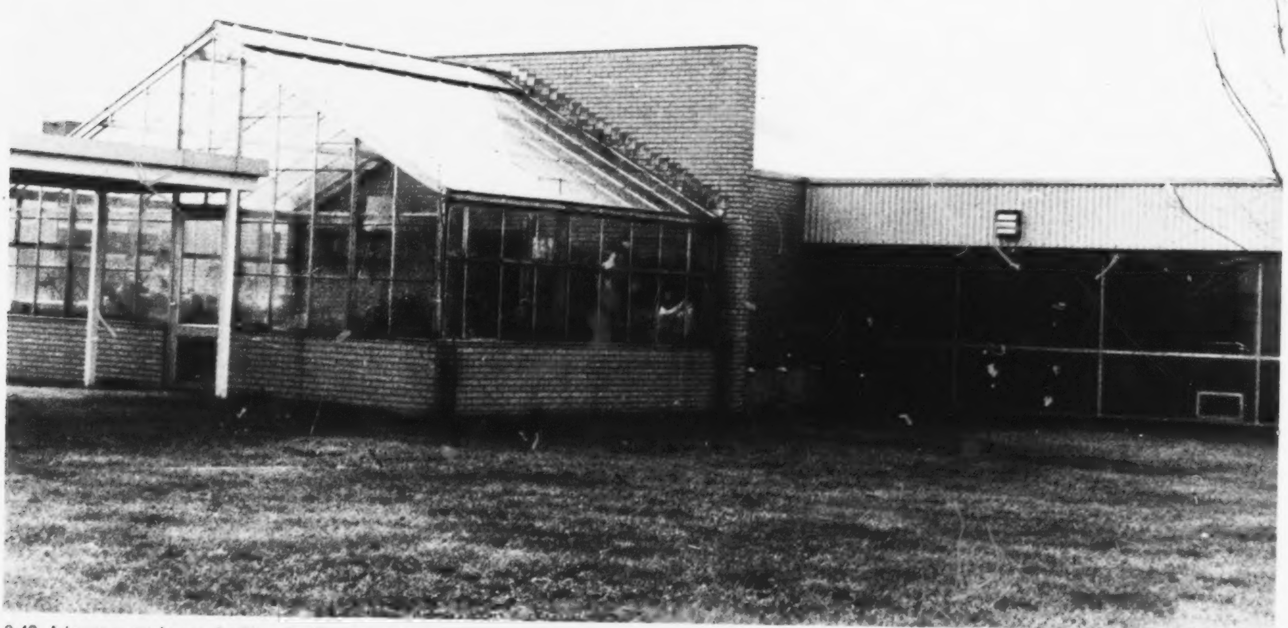


3.47 A small greenhouse on the south wing of a science building. John Burroughs School.



3.48 An interior view of 3.47 showing plant materials used for classwork and project work.

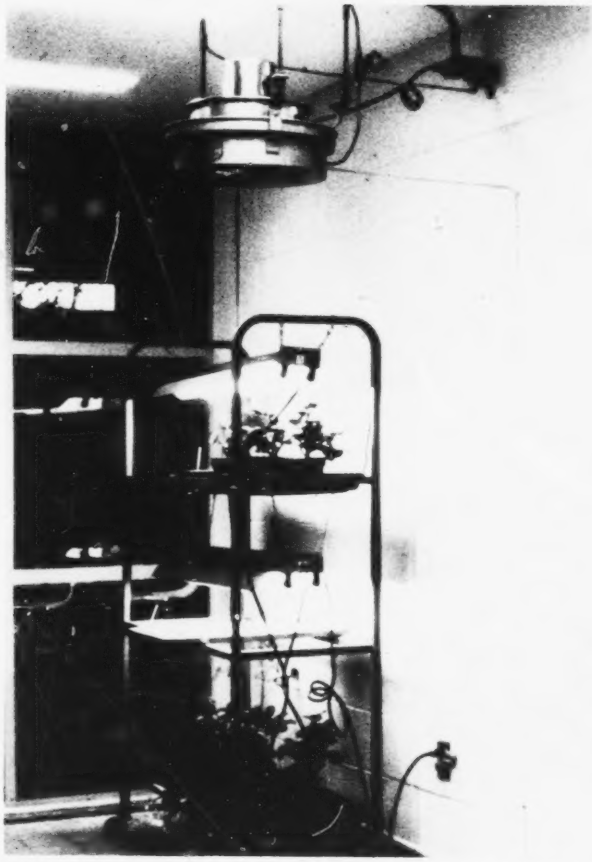
3.50 A greenhouse facility of the "lean-to" type at Concord High School.



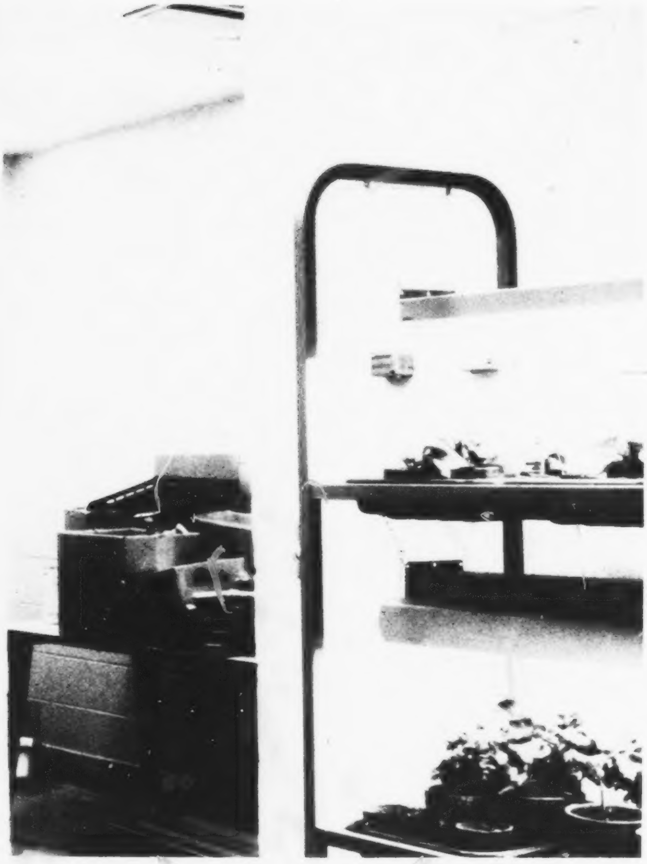
3.49 A large greenhouse facility of a New York high school. Niskayuna Senior High School.

Areas for Special Projects and Special Purposes

For most schools, especially where staff turnover can be expected, a much more satisfactory arrangement for plant-growing facilities is to have a room set aside specifically for this purpose. Figures **3.51-3.54** show some examples of plant-growing rooms. With tile floors including floor drains, humidifying units, and banks of rolling plant-growth shelves, these facilities can be excellent for individual experimentation as well as for supplying classroom needs. The illuminated rolling shelves can be easily moved to classrooms for the plant-growth activities of the class and then rolled back to the security and favorable environment of the plant room. The plant room in Figure **3.53** is adjacent to a hallway, providing an attractive decor as well as functional space. Some teachers have used plant-growth shelves right in their classrooms as shown in Figure **3.54.** However, humidity conditions in most classrooms require that the plant-growth shelves be covered wholly or in part with plastic. This arrangement is not totally satisfactory, and it is less convenient than providing for plant facilities in a special room.



3.51 A plant-growing room. The humidifier unit is shown in the upper left and a potting and work area is shown in the center rear. Greenwich Senior High School.



3.52 A plant-growing room that is also used with facilities for project work. Thomas Jefferson Senior High School.

Areas for Special Projects and Special Purposes

One of the advantages of planning for plant-growth rooms, rather than greenhouses, is that they can be conveniently located near other science facilities. They need not have any external exposure which might interfere with architects' plans for the building as a whole. The rooms must be ventilated and heated separately to maintain proper temperature and humidity. Greenhouses are frequently difficult to maintain both in terms of environmental conditions and usable stocks of healthy plants. There is also a problem of vandalism. To decrease damage from vandals, greenhouses are sometimes located on the roof of school buildings, but the facilities then become relatively inaccessible to students. In most cases it is impossible to roll a cart full of plant materials from a roof greenhouse to classrooms where these might be used. Solar radiation during the fall and spring turn most greenhouses into bake ovens unless very good, automatic ventilation is provided or other arrangements are made to reduce the amount of radiation penetrating the facility.

Some schools have found that the use of translucent plastic over the roof and sides of greenhouses effectively controls the problem of excess solar radiation, although these panels have to be removed during winter months for effective growth. In spite of the many disadvantages of greenhouse facilities, there is some desirable psychological value, and possibly some career orientation, when well-maintained greenhouses are available for project work or other class activities. Where sufficient staff interest and community support exist, greenhouse facilities should be planned at the time of construction.

All science facilities also need areas for the maintenance and storage of animals. We regard the planning of plant-growth rooms (or greenhouses) and animal rooms as necessary features of good science facilities. Special animal rooms are an important resource for student projects or for maintenance of live animals for general study.

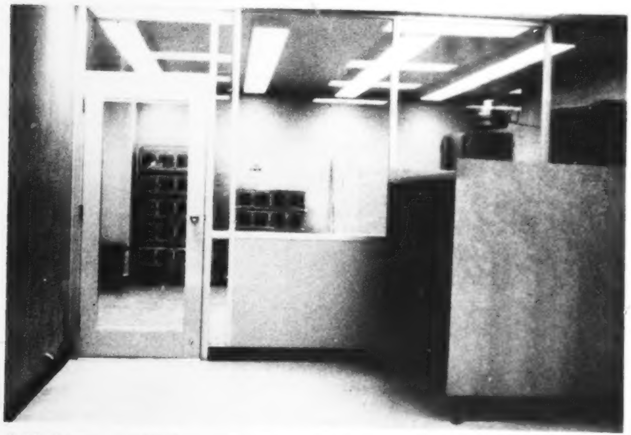
3.53 A plant-growing room adjacent to a hallway. L. E. Berger Middle School.

Figure **3.55** shows cages on a rolling cart. The animal rooms shown in Figures **3.56, 3.57,** and **3.58** are adjacent to a science laboratory, although both have ventilation systems independent of the other school rooms. Animal experiments, feed mixing, and maintenance of cages are done in the room shown in Figure **3.58.** Doors leading to two animal rooms can be seen in this view. The entire facility has its own air-conditioning and humidity controls. Figure **3.59** is an animal room located next to a hallway, similar to the plant room shown in Figure 3.53.

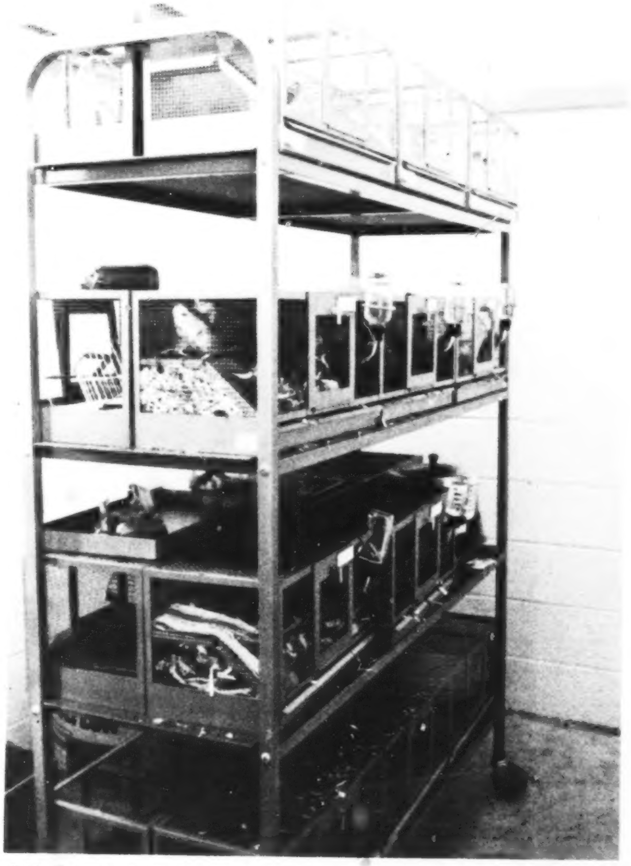
Cleanliness is always a problem, and cages will need to be cleaned regularly. Floors for animal rooms should be concrete or tile with a drain to allow for "hosing down" the room. A large sink (20 x 40 inches or more) should be available.

3.56 An animal room adjacent to the science facilities. Charles A. Lindberg Senior High School.

3.54 A plant-growing shelf covered with plastic to maintain humidity level. Little Falls Central School.



3.57 Another animal room facility conveniently located adjacent to science laboratories. Greenwich High School.



3.55 Animal cages on a cart in an animal room. Concord High School.

Areas for Special Projects and Special Purposes

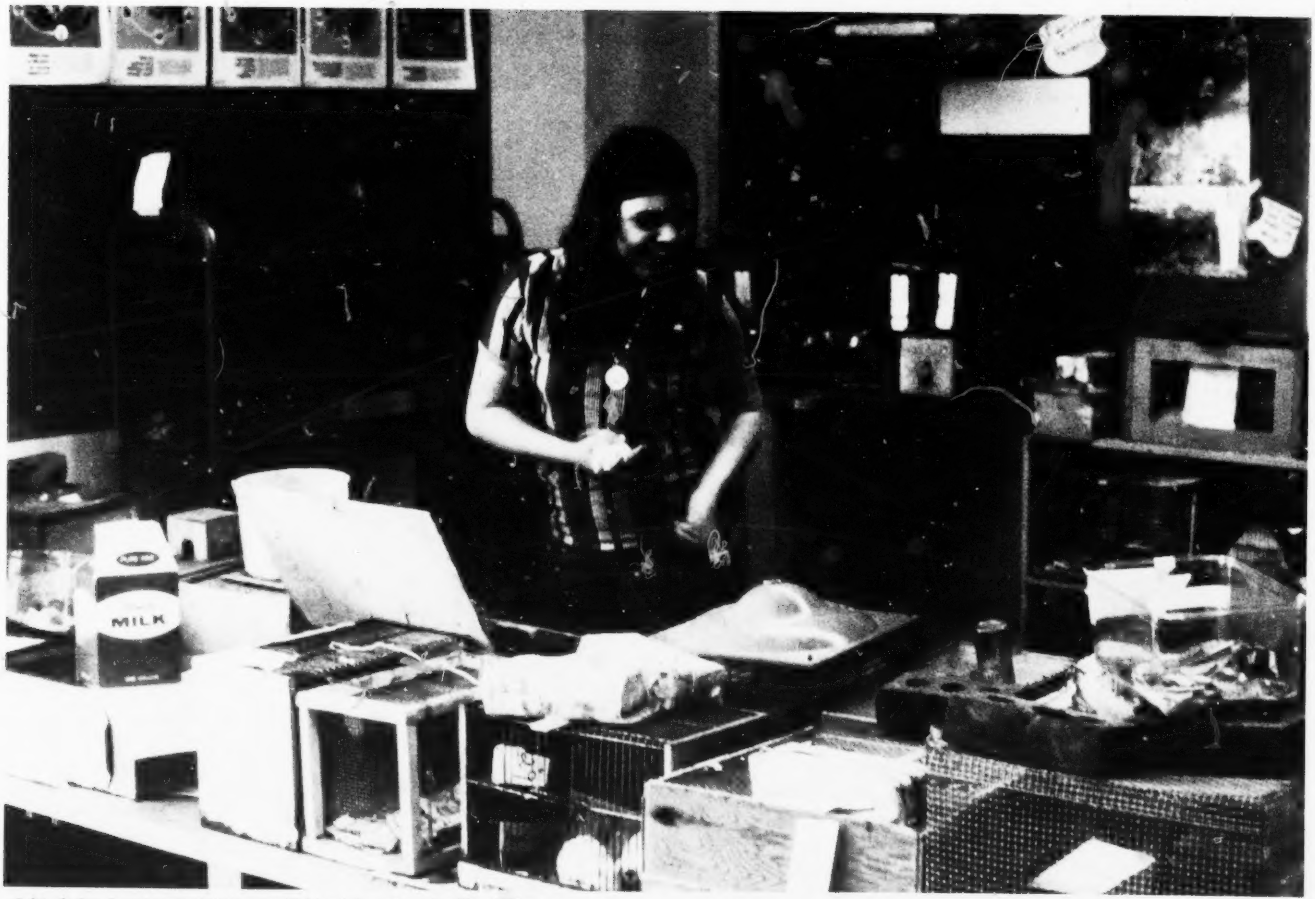
3.58 Feed-mixing and maintenance area adjacent to animal rooms. Two animal rooms are to the left rear of this view. This area is also used for project work involving animals. John Burroughs School.

3.59 An animal room adjacent to a hallway in a high school. Maine Township High School North.

The main difficulty observed with plant and animal rooms is the lack of proper heating and ventilating. Relatively high humidity must be maintained in plant-growth rooms. Animal rooms also require humidity controls, but with lower humidity levels than those for plants. Depending on the kinds of animals maintained, odors can become serious problems. Animal rooms should be ventilated separately from the rest of the building. Because of the variety of humidity-control problems, both plant and animal rooms should have independent ventilation and heat controls.

Alhough separate plant and animal rooms are highly desirable, it is possible to maintain living organisms within the classroom through other arrangements. Figure **3.60** shows animal cages in storage cabinets in an open science area. In **3.61** we see a number of animal cages and terraria in a multipurpose room in Wilson School. When living materials are easily accessible to students, project work is encouraged. These special studies in progress by students can benefit everyone.

3.60 Animal cages and terraria within cabinets in an open science facility. Little Falls Central School.



3.61 Animal cages maintained within a laboratory facility. Wilson School.

Areas for Special Projects and Special Purposes

Another type of special project area is the outdoor laboratory. Figure **3.62** shows an ecosystem being developed at a California school. Beginning with a vacant lot adjacent to the science wing, students and science teachers are creating a variety of aquatic and non-aquatic habitats. They have found it necessary to fence the area to prevent damage from vandals. Considerable work and ingenuity were needed to control moisture levels in some areas to maintain swamp conditions in the dry California climate. This project is providing an experience for students not only in the study and maintenance of ecosystems, but also in some engineering problems associated with the maintenance of the environment.

Figure **3.63** shows an artificial lake created on the campus of a private school. This large lake provides for ecological studies and is a very positive aesthetic feature. The woods and fields surrounding the lake provide areas for other project work associated with environmental studies. Many new schools visited have reserved an acre or more close to the science building for the development of a natural environment. While this task requires tremendous energy on the part of students and staff, the development of the area can be an educational experience in itself. Project teams can be assigned responsibilities for certain developmental activities. Frequently, it is possible to obtain free assistance from construction contractors and other businessmen to assist on certain aspects of the project.

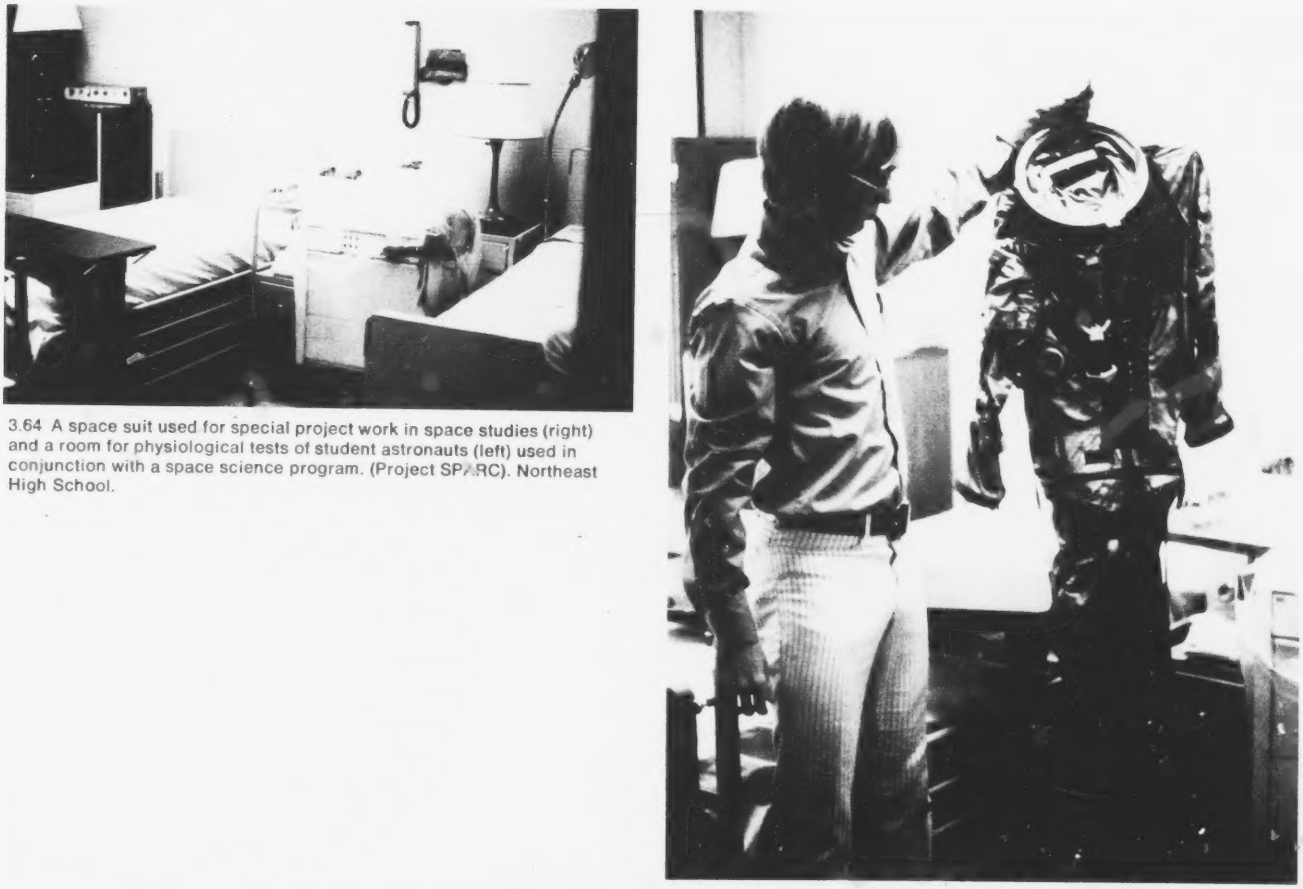
3.63 An artificial lake developed for ecological study on the campus of a private academy. University High School.

3.62 An area being developed for ecological study in a California school. Marian Peterson High School.

A very different long-term project activity utilizing special facilities has been developed at Northeast High School in Philadelphia, where Project SPARC involves high school students in a continuing program of space studies. Over the years, teams of students have designed and assembled an enormous array of electronic and other equipment for monitoring students in simulated roles of space travel. A space capsule is being developed which can allow for the study of psychological and physiological behaviors of "student astronauts" under conditions similar to those occurring in space travel. Figure **3.64** shows two scenes from the SPARC program.

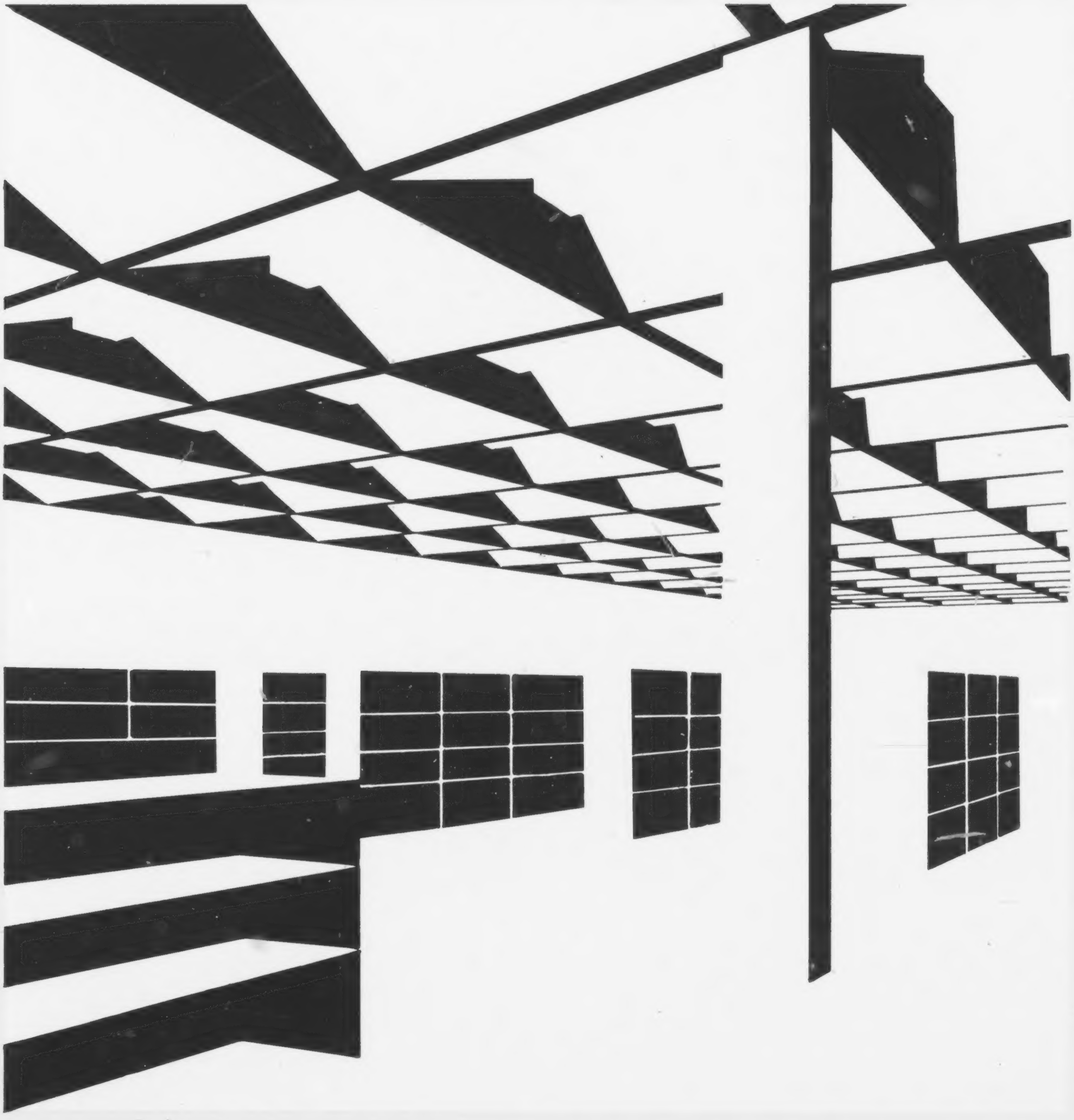
Only a small sample of potential project areas observed during this study have been described. Many excellent facilities for project work are available through nature centers, public museums, hospitals, and other agencies. A wide array of community resources can provide facilities for special project work. We have cited some references in the bibliography that illustrate community resources of value to science programs.

We do wish to raise one caution with respect to special project facilities. Too often these facilities are made available only to students who are already performing at high levels and achieving substantial recognition in the school through science and other programs. Science project activities become one more source of ego satisfaction for a very limited number of students and one more irritant for the underachieving or disadvantaged student who feels shut out by the establishment. If science programs are to contribute to the development of the mind and personality of all students, facilities should be planned for the "turned off" student as well as high achievers. We would decry facilities and programs that increase the alienation between students, a situation that too often prevails when special project facilities are available only to the students who conform closely to traditional standards on academic achievement.



3.64 A space suit used for special project work in space studies (right) and a room for physiological tests of student astronauts (left) used in conjunction with a space science program. (Project SPARC). Northeast High School.

Chapter 4



Construction Details

In working with architects to plan for new or remodeled facilities, school people must recognize the importance both of the limitations and the potentials of design. Many architects have had only limited experience in the design of newer types of science facilities. Therefore, they need guidance as planning proceeds. This chapter illustrates a variety of facilities observed, with commentary on the relative merits of alternative construction details. Our assessments are based on the assumption that facilities which increase the ease with which new programs can be accommodated are more desirable than are facilities that severely restrict instructional options.

Throughout this section we call attention to potentials and limitations of design alternatives for augmenting humanisn in schools. For every alternative design feature, we believe it is important to consider how pupil-pupil associations and staff-pupil associations are enhanced.

The previous chapter illustrated a sampling of various types of instructional areas found in the exemplary facilities studied. Two particular features were noticed in these facilities: **provisions that allow for easy access to information from a wide variety of sources and a trend toward greater flexibility in space utilization.**

The first trend is toward more types of instructional areas within the science facility. Activities which occur within the instructional area of the science facility include seminars, lectures, laboratory experiments, and independent study. Although these various activities could conceivably occur in the same area, it would be desirable to have a variety of specialized areas in addition to an area for integrated learning. Each such specialized area should serve several instructional purposes.

The second trend, flexibility, would allow a space to be used for laboratory work at one time, for small-group seminars at another, and even for technologically mediated study at another time. The area must serve its original purpose well, but it must also be easily and inexpensively adapted to another purpose. This chapter will describe characteristics of facilities which give them flexibility.

Acoustics

Control of sound levels in various spaces in a school building is an important design feature. In traditional facilities, the primary means of isolating spaces acoustically was to install massive walls and doors. The spaces created in this way still were not shielded from extraneous noise. Consequently, one of the primary concerns of teachers and principals in traditional school facilities has been the relative amount of noise in rooms or halls. Many unfortunate instructional practices have their origins in the miserable acoustics of most traditional school facilities.

In recent years, new fibers and new carpeting are having a very important bearing on acoustical treatment in schools. In fact, the new potentials created in the design of flexible instructional space through the use of these carpets might be compared to the potential created for airplanes with the advent of the jet engine. When hallways and other areas are carpeted, the noise problems associated with students moving about the building while other students are engaged in some form of study are largely eliminated. This means that a school may move to open scheduling and other forms of differentiated activity for individual students without unacceptable noise levels throughout the instructional space. Within a given area, students can engage in widely differing activities and still interfere minimally with their classmates who might be involved in quiet study.

Sounds should be absorbed at the point of origin, not at some distance from the origin. Since approximately 90 percent of the noise in a school originates at or near the floor, carpeting is a vital feature in acoustical treatment of instructional space. Our recommendation is that any floor area, with the possible exception of plant-growing rooms and animal rooms, should be carpeted. We have not found any carpeted school space that has proved to be unsatisfactory in the experience of teachers and administrators in that school.

Carpeting not only lends acoustical value in school design, but it also enhances the environment in an affective dimension. With carpeted floors, students are commonly observed sitting on the floor in small groups exchanging experiences or discussing their class work. Carpeted floors permit students to interact in ways that encourage development of human relationships. We have stressed throughout this report that new facilities must consider the human qualities of the environment as well as instructional variables. (Figure **4.1**) Figure **4.2** shows a large, open, carpeted area in the Plantation Middle School in Plantation, Florida.

4.1 Carpeting makes hallways and every area a potential study space. Little Falls Central School.

From the studies that have been made by the Educational Facilities Laboratories [10], two recommendations are made: (1) Treat only the floor acoustically. When both the ceiling and floor are treated, the problem of "acoustical deadness" may arise. The sound is absorbed too fast, and voices will not carry as far as they need to. A carpeted floor absorbs unwanted sound where it starts, while a hard ceiling will reflect sounds to where they are wanted. (2) Have the total dimensions of the room large enough so that there will be enough separation between groups — space large enough to act as a barrier to sound conduction — and keep the population of the space within the number planned for the room.

In the open-plan schools carpeting seems to be generally accepted as a necessary feature of acoustical treatment. Although carpeting is somewhat more expensive to purchase and install than is a resilient floor covering, there may be long-term savings. At Andrews High School, Andrews, Texas, [11] it was found that the cost of the low-bid carpet plus luminous ceiling was the same as the cost of vinyl tile plus an acoustical, luminous ceiling. Because maintenance costs are so much less with carpeting, it is estimated that the carpeting will be paid for through the savings within 7 to 10 years. School officials at Andrews claim that upkeep costs for carpeted areas are 50 percent less than those of uncarpeted areas and use 20 percent fewer man-hours. In 1965, carpet cleaning supplies for Andrews High School cost a grand total of $55 for the year.

Stanislaus State College similarly reports significant savings by using carpet. This college has initiated a maintenance contract which provides carpeting in designated areas. The Stanislaus business manager states that

> "At *current salaries* and with no provision for cleaning materials or equipment, the contract would save a minimum of $11,000 per year over direct hire. Including the requirement for cleaning materials, equipment, and pay increases, the projected savings in the first year are $28,000. What is not shown . . . is the indirect savings in administrative costs such as recruiting, personnel actions, payroll, workmen's compensation insurance, etc." [12]

The obvious advantage of carpeting is in the ease of maintenance.

4.2 A large carpeted open school used for many kinds of studies including science. Plantation Middle School.

Concerns or fears about carpeting have included cost, resistance to physical and chemical wear, and static electricity. The previous paragraphs have included figures from two schools which indicate that carpeting, because of its ease of maintenance, can be less expensive than other forms of floor treatments. All schools visited in this study which had used extensive carpeting reported similar savings and satisfaction. The carpet may show physical wear in areas subjected to very high traffic, such as main access points to instructional areas, auditoriums, and near outside doors. This problem has often been overcome by leaving a few yards of the most highly traveled areas uncarpeted or using carpet tiles which can be replaced. The most traffic will result in the most noise, and if there is no carpeting in these areas, that noise may be disruptive. It may be worth the extra expense of more frequent "patch replacement" in highly traveled areas so that a quiet environment is maintained. Figure **4.3** shows a carpeted main corridor in a new high school. At Mariemont High School in Cincinnati, carpet tiles are used at entry ways and in other heavily traveled areas. Very few tiles have had to be replaced, but the process is so simple that custodial workers can do whatever replacement is needed.

4.3 Carpeted corridors reduce the noise from students moving through a building and make corridors pleasant areas for informal association. Little Falls Central School.

4.4 This chemistry area in an open science laboratory is completely carpeted. Little Falls Central School.

The question frequently arises as to whether or not carpeting can be used in chemistry laboratories. Figure **4.4** shows a chemistry area in an "open" school where all floors are carpeted. In many ways a chemistry laboratory is similar to a kitchen. Many homemakers are finding that carpeted kitchens not only are much easier to maintain, but that the carpeting is almost unbelievably resistant to stains ranging from raw eggs to spilled bacon grease. At Mariemont High School the entire student lounge and cafeteria areas are carpeted (Figure **4.5**). We have observed carpeting in several science facilities, including the chemistry area of the facility. In no case were any reports of dissatisfaction received. On the contrary, teachers were enthusiastic about the carpeting. In some schools where carpeting was not installed in the chemistry area, but installed in other regions, teachers reported that they know of no reason for the decision, nor have they had experiences which would not support the use of carpet in chemistry areas. Our position is that science rooms, including areas used for chemistry experiments, should be carpeted. In some locations, it may be useful to have plastic runners that can be placed over small areas if especially hazardous chemicals are being used. Plastic runner material, similar to that sold for corridors or other spaces in homes, is inexpensive and can be rolled up and set aside when not needed. The acoustical value of the carpeting remains at all times.

When carpeting is used, it is sometimes necessary to add plastic caps to chairs or tables. Some older furniture with steel legs will produce rust spots on the carpet, especially if water is spilled.

The buildup of static electricity has been a problem in some schools where carpeting is used. This problem can be avoided in several ways. Many schools are now provided with heating and ventilating systems that maintain an appropriate humidity level throughout the school year. When proper humidity levels are maintained, static electric charge is not a problem with carpet. For older facilities in which humidity is not controlled, carpeting that resists charge buildup is available. There are also chemical treatments that can be applied to carpeting to reduce buildup of electric charge. While this consideration cannot be ignored, it can be dealt with relatively easily.

4.5 Carpeting in student lounge areas adds to the comfort and pleasure of these areas. Mariemont High School.

Acoustics

Reactions from the people in schools where carpeting is used are overwhelmingly favorable. Teachers — especially those who stand and move about much of the day — report that they do not become as tired. The staff believes that carpeting seems to affect the behavior of students in that there is less littering and vandalism in carpeted areas than in uncarpeted areas. A number of teachers have reported that the students seem to respect one another and act more courteously toward the staff in carpeted facilities than in uncarpeted facilities. Part of this may be a secondary effect produced by the relatively greater freedom given students to move about in carpeted areas, since noise is less of a problem and the children are not reprimanded. An open carpeted area is shown in Figure **4.6.**

In addition to improved acoustics, carpeting also has aesthetic value. Many carpets are very well designed and when used in differing combinations of colors, they can create a highly attractive environment.

Acoustical treatment of ceilings and walls is sometimes necessary. As noted earlier, it is possible to eliminate too much sound reverberation through acoustical treatment. This should be avoided, but any experienced architect can design facilities that will not be "dead" with respect to sound. Some examples of user criteria concerning acoustics of various instructional areas are included in Appendix 3.

4.6 Carpeting allows multiple activities in an area without excessive noise and has an apparent positive effect on student behavior. Little Falls Central School.

Internal Walls

We have discussed how acoustical control can be managed in space without primary dependence upon walls. What functions are associated with walls and what other options are available to serve these purposes? Some of the functions performed by internal walls are:

1. Support of the ceiling — weight supporting
2. Coverings for pipes, wiring, atmosphere-control ducts
3. Acoustical separation of space
4. Visual separation of space
5. Storage surface
6. Work surface
7. Secure storage
8. Fire control

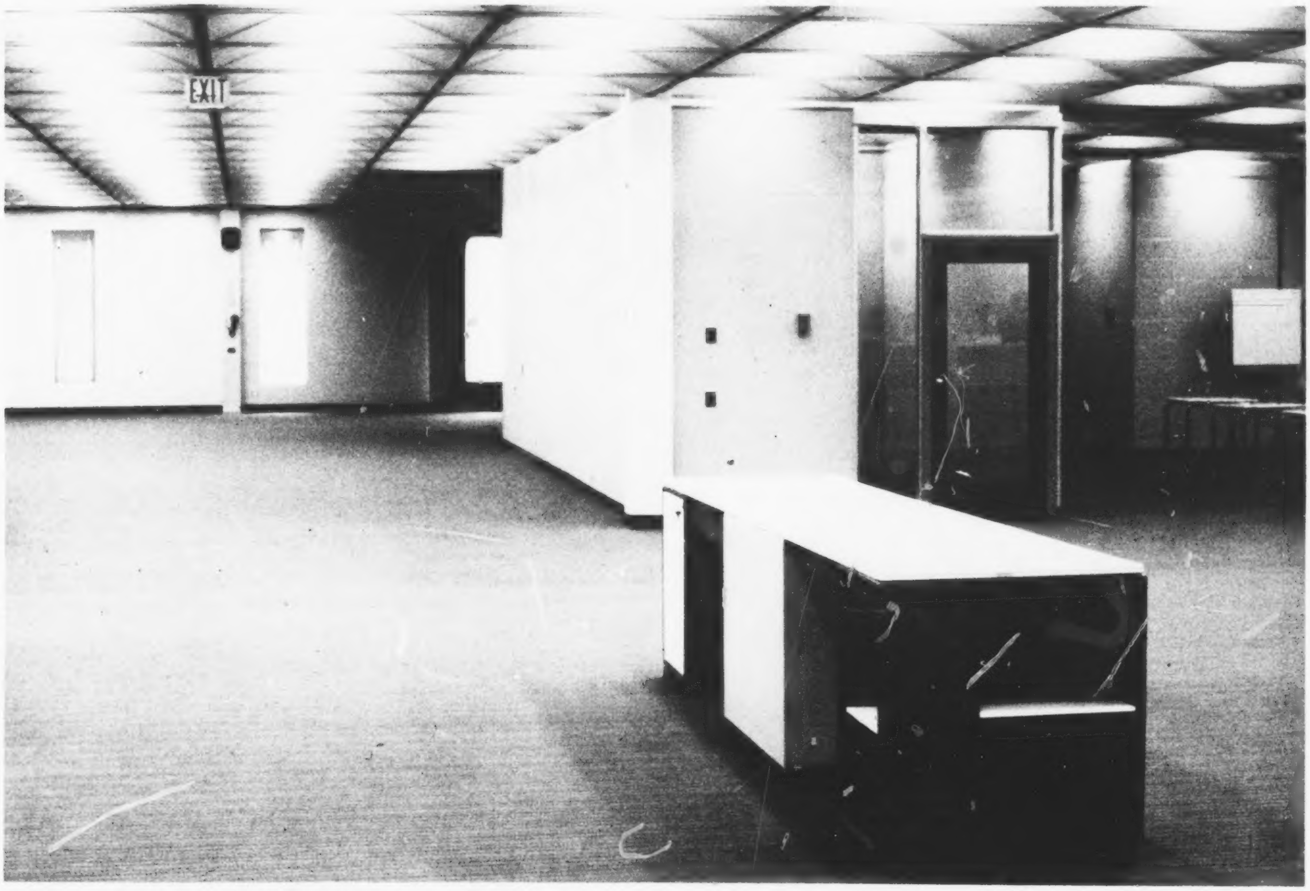
The above-listed functions must somehow be accommodated in a building, but seldom are heavy walls necessary; these functions can be accomplished in other ways. Present-day construction technology allows the building of rooms with a standard ceiling height as large as 110 feet across without any internal weight-supporting walls. [13]

The other uses of walls must be examined to determine whether these functions will justify the limitations in flexibility imposed by internal walls.

The mechanical subsystems of a school, such as its lighting, air-conditioning and heating ducts, electric supply, TV conduits, and the like, can be located in a ceiling "service sandwich," as described later in the section on atmospheric considerations. An article entitled "Ceiling Systems Give Partitions a Push — in All Directions" [14] describes a system in which a ceiling grid is interlocked with a movable partition system.

The coordinated ceiling is composed of a grid-system of from 4- to 10-foot modules. Basic to the system is a grid trough with sides of acoustical material.

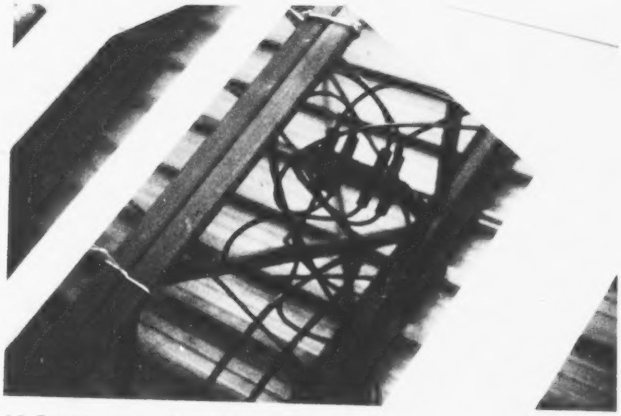
Housed within the grid troughs are: electric conduits; ducts for hot, cold, and return air; fluorescent light tubes; telephone lines; electric wiring raceways, switches, outlets, and low-voltage wiring for TV, radio, clocks, and the intercom system. Regardless of how the interior partitions are moved around, the various grid elements can be adapted to the desired activity. [14, p. 71] The room shown in Figure **4.7** could be relocated in any part of the large open area.



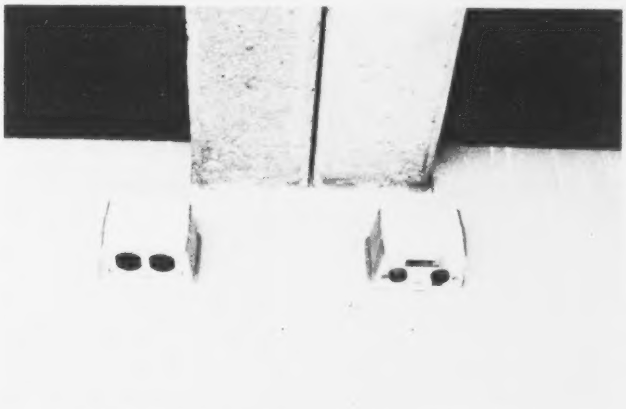
4.7 A small seminar room located in a large open area. This room can be enlarged or moved easily.

Figure **4.8** shows electric connections above ceiling panels, and Figure **4.9,** the finished ceiling. Figure **4.10** shows a ceiling-to-floor service column which contains electric outlets, TV hookup, a clock, and intercom. The whole column can be easily disconnected and moved to another position in a room.

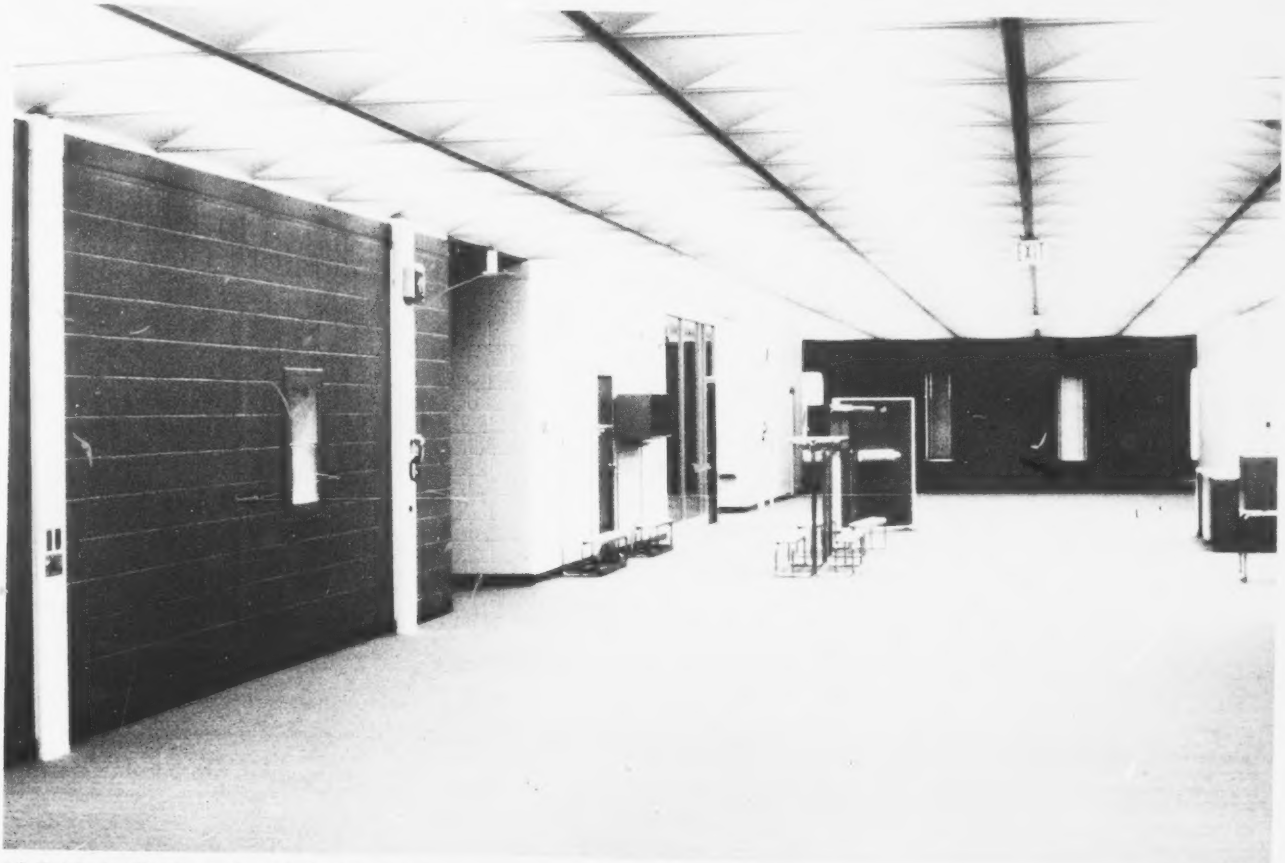
In some of the schools visited, the electric outlets are located in the open area on the floor. (Figure **4.11**) This floor location reduces flexibility in the use of a given space. Where laboratory installations are needed, facilities such as the lab islands shown in Chapter 3 provide for plumbing without the use of wall enclosures and with plumbing connections only on peripheral walls and in permanent fume hoods.



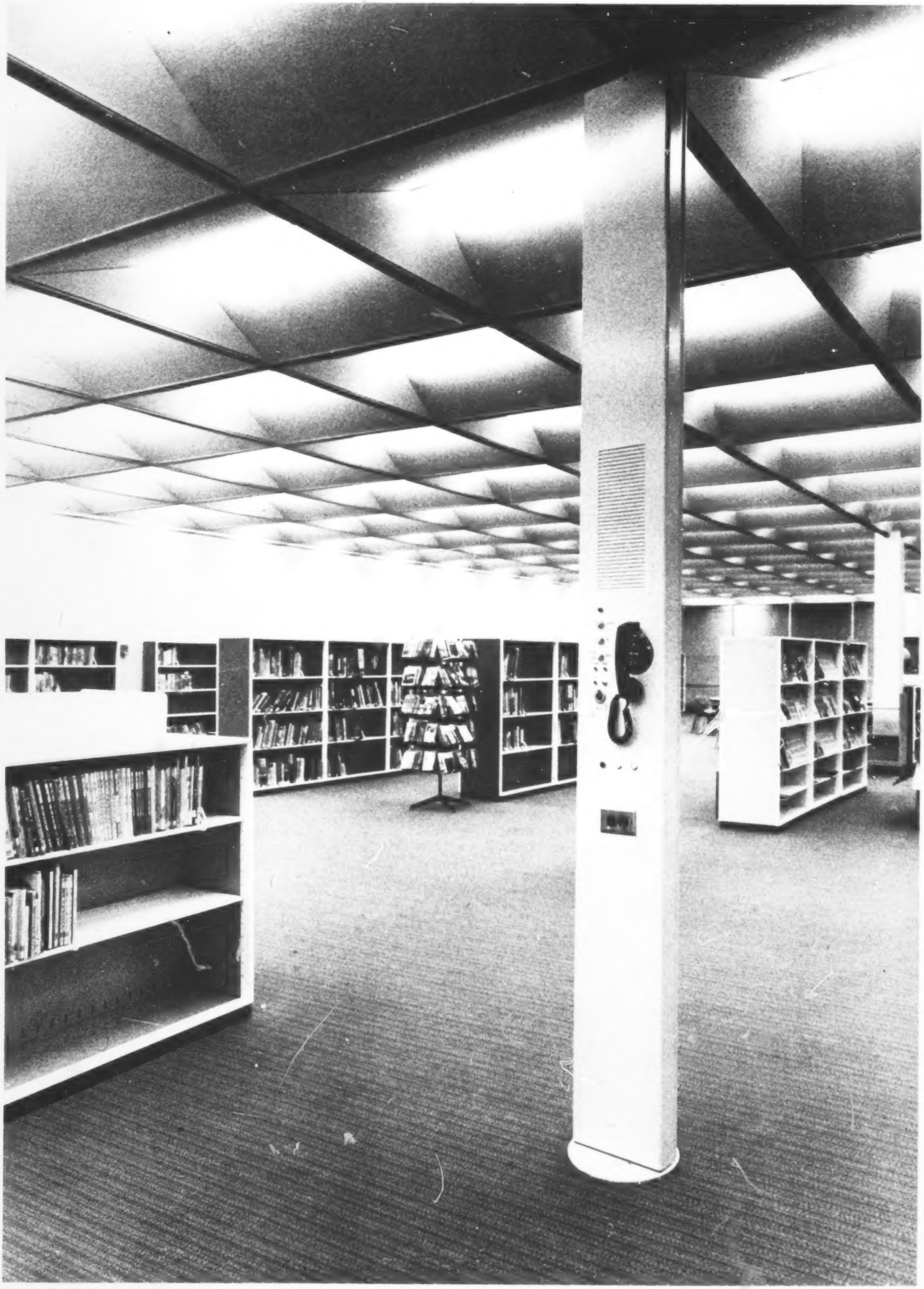
4.8 Electric connections above ceiling panels.



4.11 Floor outlets such as these cannot be easily relocated and frequently interfere when room rearrangements are desired.



4.9 Finished ceiling in a systems designed school.



4.10 Service column between floor and ceiling. This unit plugs into electric and intercom connections within the ceiling. It can be located in almost any position in the room.

Internal Walls

Acoustical separation of space has often been accomplished by use of large, massive walls. However, the Director of Educational Services of Hough Manufacturing Corporation stated that

> "with the popularity of good acoustical ceilings and carpeting (even in science facilities) we have noticed a trend away from heavier, more expensive sound-retardant partitions. The acoustical ceilings and carpeted floors act as sound absorbers, thus reducing the requirements for massive walls." [15]

Besides the use of acoustical treatments on the floor and/or ceiling, adequate physical spacing between groups and avoidance of scheduling a group which requires quiet and another which will be noisier in adjoining spaces at the same time will contribute to making an open area adequately quiet. Some walls may be desired to isolate one space from another acoustically and visually. For this purpose there are many types of movable walls. The operable or moving walls include the accordion partitions shown in Figure **4.12** and rigid folding-panel sliding partitions (Figure **4.13**). Other partitions are put into place, then inflated to press the ends against the ceiling and floor.

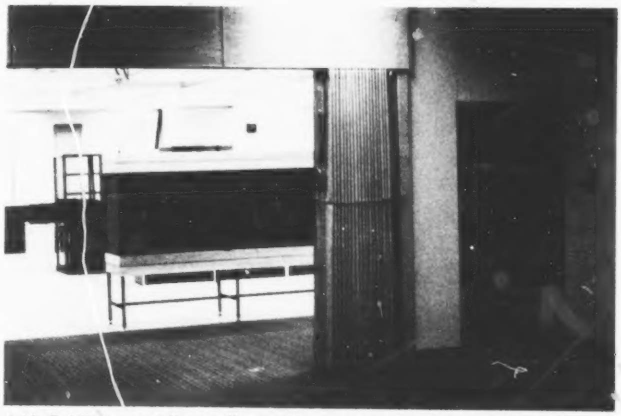
One criticism of the operable wall is that its track is fixed, and, although it can be opened and closed, it can not be changed in location. [16] However, one school reports installing a grid system in the ceiling which allows the operable walls to be changed in position. [17]

Many walls which are, in theory, movable or demountable are never moved. Teachers and maintenance people may not make the effort to move them. The walls shown in Figure **4.14** for example, would be difficult to relocate.

The technology of wall design and installation is changing rapidly. By the time this study is published, there may be new types of walls not now in existence which will solve some of the problems of demountable and operable walls. The suggestion is made, however, that no internal floor-to-ceiling walls may be needed at all, no matter how easy they are to operate or how inexpensive. Alternatives to floor-to-ceiling walls should be considered for most instructional areas.

An alternative to the floor-to-ceiling wall is described in an Educational Facilities Laboratory report entitled *Schools Without Walls*. In a description of one school the report states that

> "Preliminary plans called for operable walls which would make it possible to enclose single classrooms in the lowest grades and pairs of classrooms in the upper grades. But the operable walls were abandoned, and no attempt was made to hedge by installing ceiling track to receive partitions at some future date. In the school as constructed, the original classroom wedges, each 36 feet long, 25 feet wide at the outer wall, and 9 feet wide at the inner wall, are defined only by the location of sinks, toilet rooms, and doors. If visual separation is needed, it is provided by moveable storage cabinets or other furnishings." [18]



4.12 Folding accordion walls used to separate two learning areas.

4.13 Sliding partitions between two science areas in a middle school. Vista Middleschool.

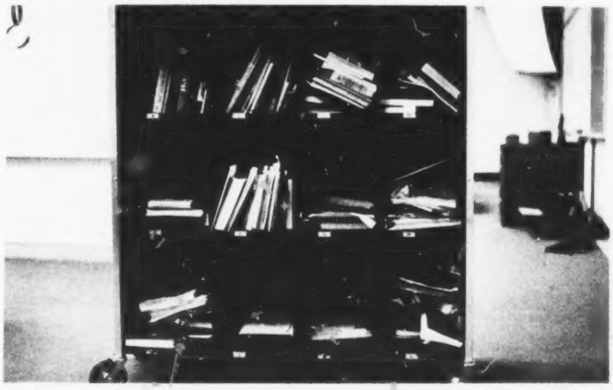
4.14 Glass wall panels used to isolate a preparation area. Greenwich Senior High School.

Visual separation may be achieved with rolling bookshelves, storage shelves, and other cabinetwork that serve just as efficiently as floor-to-ceiling walls, while allowing much more flexibility in space utilization. Figure **4.19** shows a demountable partition which actually does little but visually separate the two groups. It has little function as a work or storage surface. There are no utilities in it, and it could be replaced by tall storage cabinets and bookshelves which would be more functional. Figure **4.15** shows a common example of how walls serve as storage space. Such wall storage is inefficient at best and is very inconvenient. In one school visited, similar wall cabinets had been reversed so their backs could be used as bulletin boards. Better ways to store equipment are described in Chapter 5. Laboratory islands with movable tables, shown in Chapter 3, would provide much more flexibility in the use of this space, and the wall shown would not be needed.

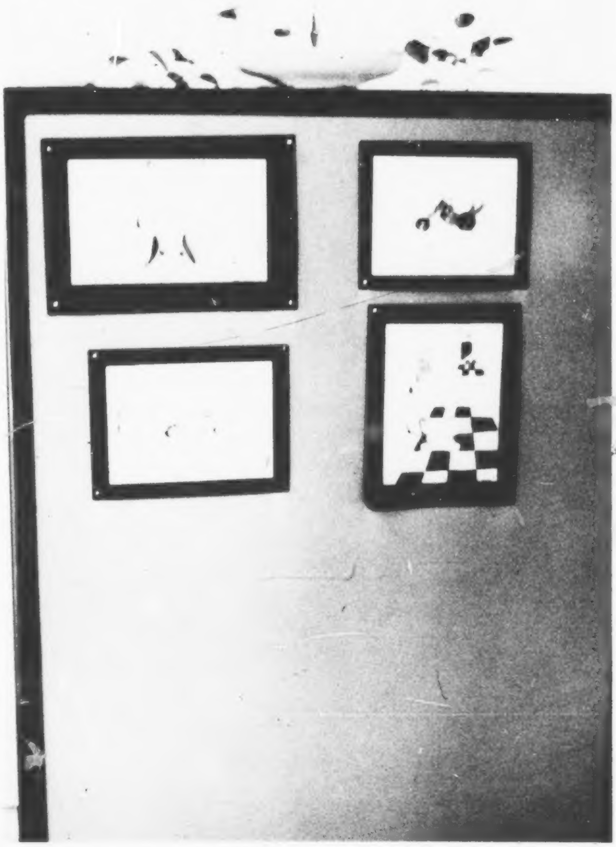
Figures **4.16** and **4.17** show examples of storage cabinets used to separate space. Notice that both areas are carpeted.

In some areas, a more substantial barrier than a row of bookshelves may be desired to store records, confidential material, expensive equipment, chemicals, and the like. Many of these items can be locked up in metal cabinets, but some walled-in areas may also be desired. Preparation and storage areas are usually enclosed by permanent walls.

4.15 Wall cabinets such as these are expensive for the amount of storage space available. They are inconvenient for students to use and are not recommended.



4.16 Rolling storage cabinets such as this can provide for short-term storage of materials needed in the immediate area of open learning facilities. Little Falls Central School.

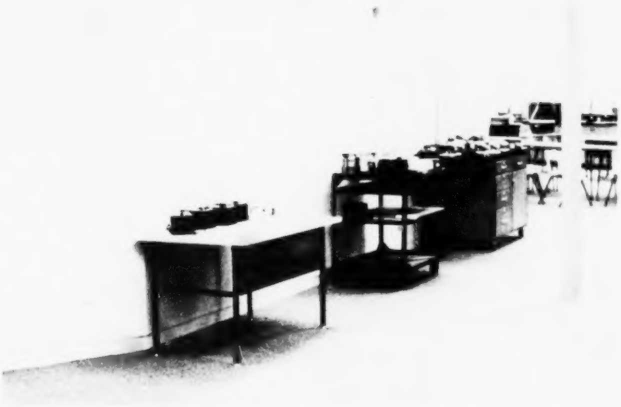


4.17 This rolling book shelf can be used to divide space and serves as a bookcase on one side and a tackboard on the other side. These bookcases can also be seen in Figure 3.38. Mariemont High School.

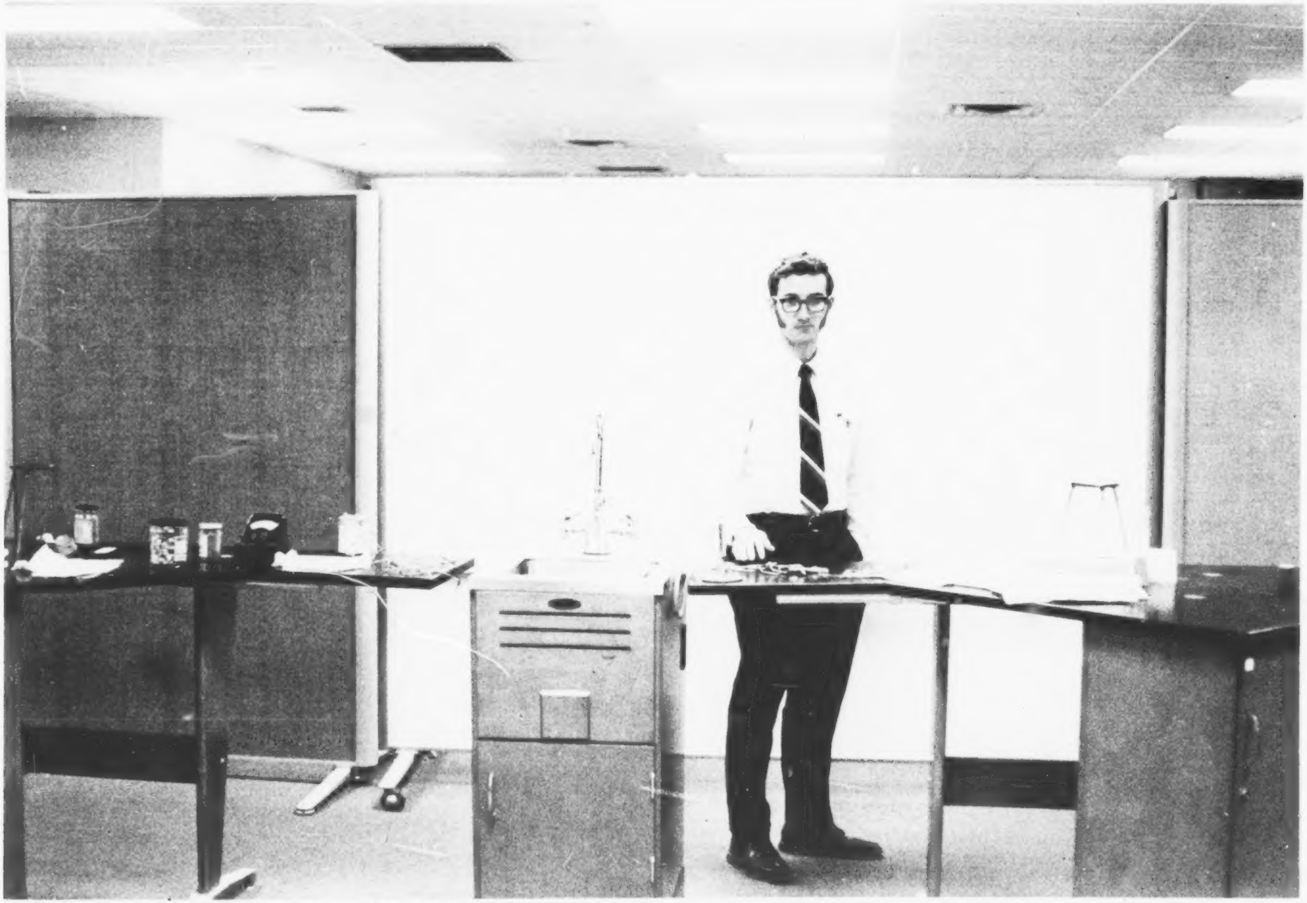
Internal Walls

Figures **4.18** and **4.19** show areas separated by work surfaces which are not floor-to-ceiling walls. Again, these areas are carpeted, and the noise level is low. These work surfaces are much less expensive than walls covered with chalkboards, tackboards, or pegboards.

Walls may also have some fire-retardant functions. Fire codes vary from place to place, but most specify what resistance to fire a given wall surface must have. However, if appropriate sprinkler systems, electronic sensing devices, or other fire prevention and warning systems are used, considerable variance in fire regulations may be permitted. Of course, if movable cabinets are used in open areas, then fire codes which specify how fire retardant a hallway wall must be are not applicable.



4.19 Seven-foot walls which are movable have been used to form a staff area within this open plan facility. Mariemont High School



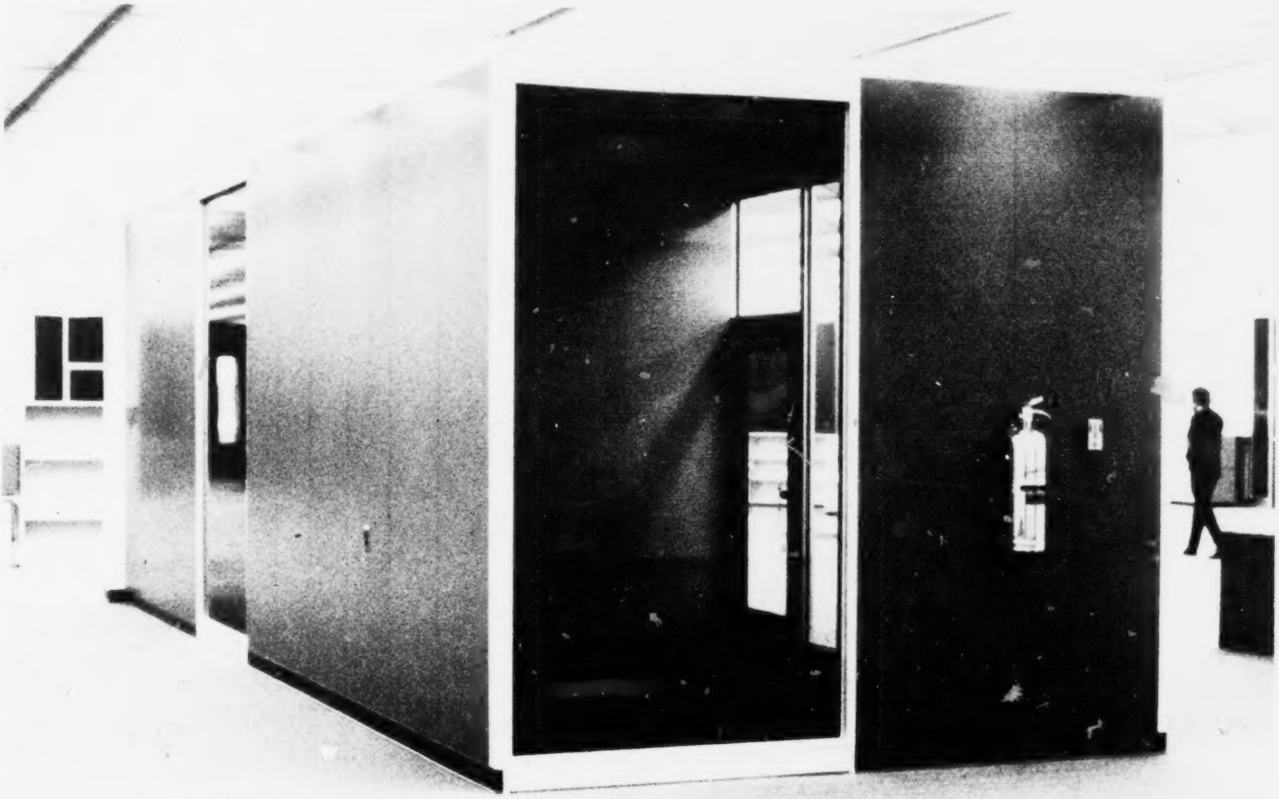
4.18 Movable chalkboards and rolling partitions provide highly flexible surfaces which are easily relocated when desired. The white chalkboards shown here are not recommended. Little Falls Central School.

Visual Considerations

Proper illumination is one of the most important items to plan for in new or remodeled facilities. Lighting should be glare free; sharp contrasts of light and dark should be minimized; and nonreflective surfaces should be used to the extent possible. [19, p. 35]

Some schools have installed luminous ceilings — translucent plastic suspended continuously beneath fluorescent tubing. Although this type of lighting affords easy maintenance and is a very efficient light source, it provides such evenly distributed illumination that there are no shadows, and the environment seems monotonous and tiring. Figure **4.20** shows another type of lighting system which provides more pleasant illumination. A seminar area has been created by using demountable walls as an island in an open area. All the utilities including the lighting system are organized in a 5 x 5-foot grid in the ceiling. All the systems in this grid including heating, air-conditioning, lighting, and electricity sources can be arranged to meet a certain need and then be rearranged for another purpose. The lighting in this seminar room is controlled by one switch. At some later date, the decision may be made to double the size of this seminar room or remove it completely. At that time, the lighting and other systems can be rearranged. In the large open space, banks of lights operated by different switches can control the amount of illumination that various areas receive.

Windows may also be a source of illumination, but they do increase the problems of heating and air conditioning. If windows are present, means should be available to block out all light.



4.20 The lighting panels in this ceiling can be controlled by easily relocated switches, permitting relocation of seminar rooms such as that shown here.

Visual Considerations

Figure **4.21** shows an area used for physics experiments. The teacher who uses this area suggested that the room would be better suited for physics if it did not have any windows. If windows or strips of translucent material are to be used, they should be placed high on walls so that movable shelves and demountable cabinet work or perimeter laboratory benches can be placed below them. Some examples of user criteria concerning the lighting of various instructional areas can be found in Appendix 3.

Other visual considerations include the capability of changing the light intensity in a certain area of the science facilities. With rear-view projection screens, films can be shown in a much lighter room than would be possible if that same film were projected onto a wall screen. However, for some experiments a darkened room is desired.

Many types of ceiling light panels are available. It is important to install a lighting system which will allow exchange of panels and rearrangement of the controls for the panels.

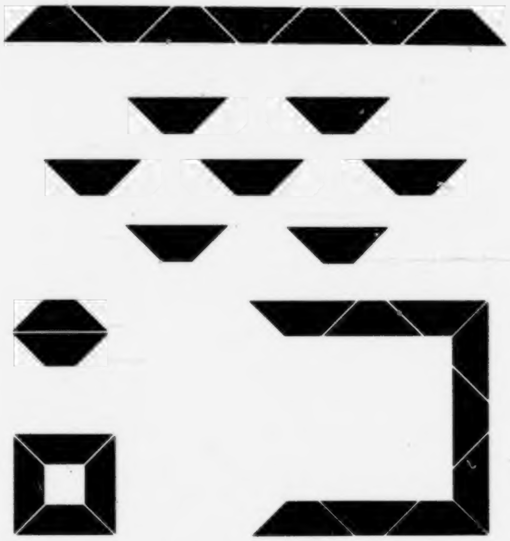
4.21 This room used for physics experiments has blackout curtains on the windows at the left when various experiments with optics are performed. Greenwich High School.

Room Furnishings

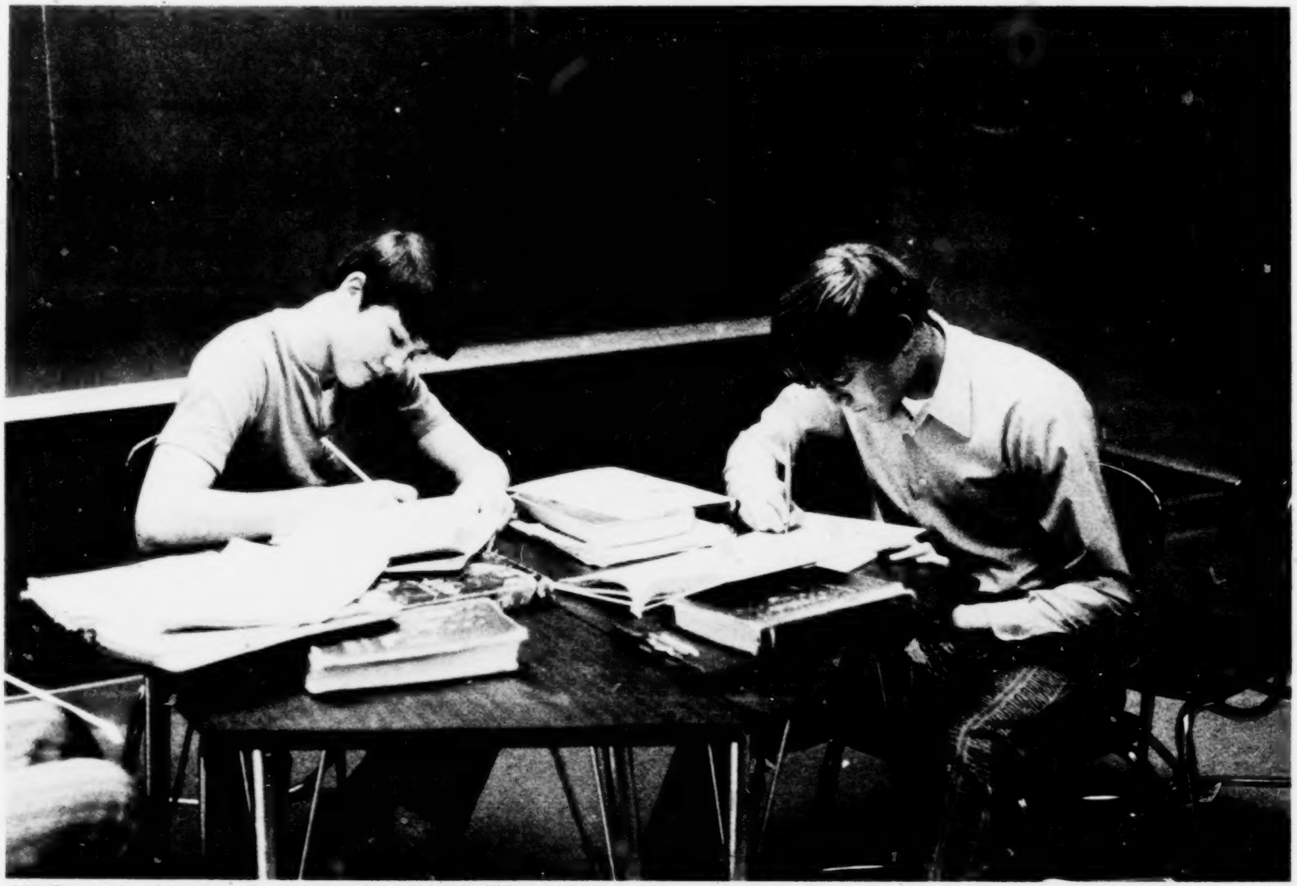
The most important single consideration in room furnishings is the floor covering. In the section on acoustics we have presented in some detail the reasons for carpeting all floors in science areas; we regard this of such importance that the need for carpeting will be stressed repeatedly. In one facility visited, small lecture rooms and a larger lecture room were not carpeted in the original planning. Even though some acoustical treatment was added to the ceilings in these rooms, extraneous noise was so unacceptable that carpeting was added later. This is a common problem in many facilities observed. Of course, adding carpeting at a later date almost doubles the cost for floor treatment. If carpeting is planned in initial construction, other advantages in cost and utility may be obtained, for furnishings can be positioned and arranged for easier cleaning and more functional use. Furthermore, the floor base needed can be less expensive than that necessary for tiled floors.

A word of warning may nevertheless be given about carpet in the chemistry lab. Spilled mercury if not properly recovered is a hazard to health. A carpeted floor is more of a problem to clean than are tiled floors with cracks. An industrial type vacuum cleaner should be used to clean up after a spill. Precautions should be taken while using mercury — use of trays beneath apparatus, plastic containers and tubing, continuous smooth surface on floor (could use plastic cover over carpet).

Movable tables are important to provide flexibility in science facilities. We have observed many kinds of tables in the schools studied, but perhaps the most functional single type of table is the trapezoid table. It can be used for laboratory work, discussion activity, for demonstrations, or for temporary carrel units. Different groupings of tables can be used for conference areas or seminar areas. Figure **4.22** shows several possible configurations of trapezoid tables. Figure **4.23** shows some of these tables in use in science facilities. Trapezoid tables can also be seen in figures shown in other sections of this report.



4.22 Trapezoid tables can be arranged in a variety of configurations, serving many different types of individual or group discussion activities.

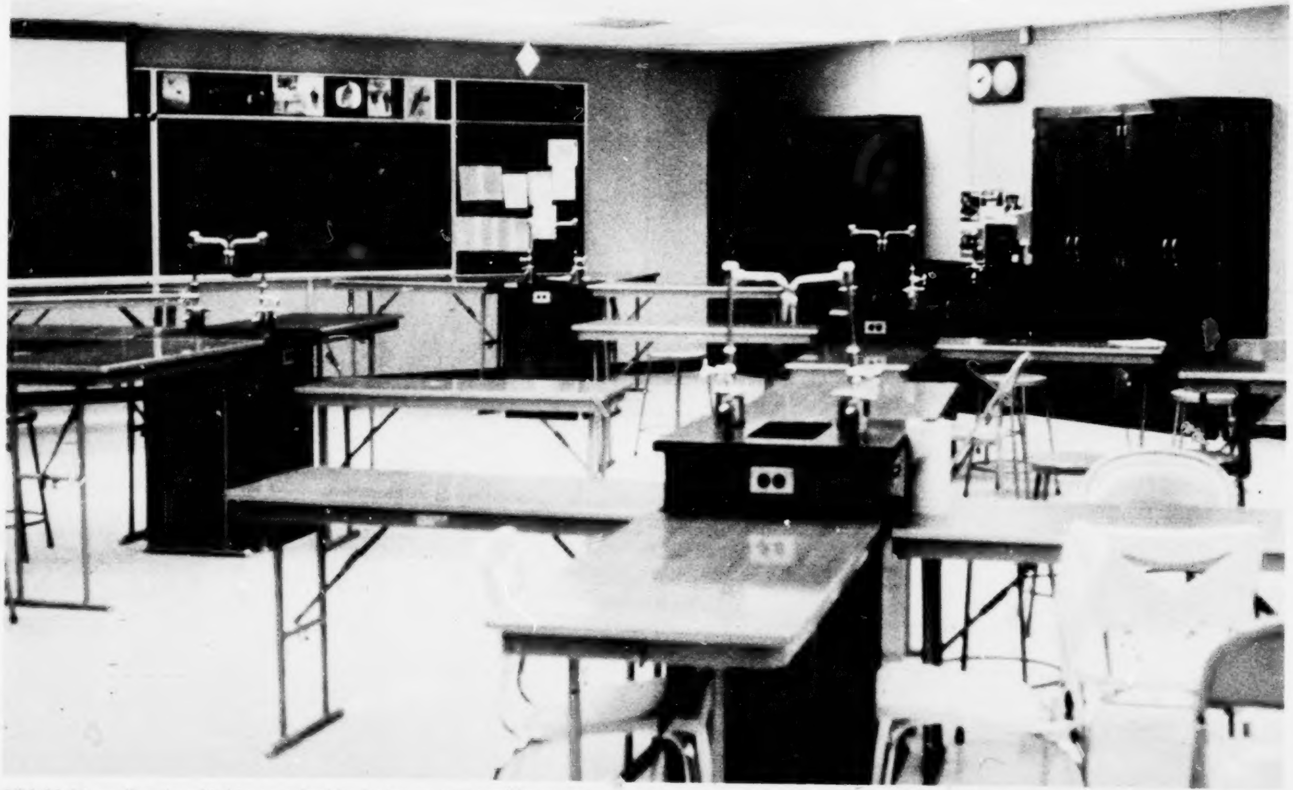


4.23 Trapezoid tables were observed in many science facilities, such as the one shown here.

Room Furnishings

Although trapezoid tables are extremely versatile, other kinds of lightweight tables are also needed, especially for laboratory work where large experiments or demonstrations are to be set up. Figure **4.24** shows some large, lightweight tables in a physics laboratory and also some more massive tables that can be used for other experiments. In Figure 3.13 we saw a table that is adjustable in height being used with laboratory islands. The science chairman in this school ordered stone-topped tables, but received instead plastic-topped tables with adjustable legs. After experience in using these tables, he was pleased that his original order was not filled. The variable-height tables permit a variety of configurations, and the plastic top has proved completely satisfactory. The tables are light and easily moved, and yet they function well for many laboratory activities. At a cost of less than $25 each, they can be replaced if unreasonable use should damage a table. The versatility of similar tables in a junior high school is illustrated in Figure **4.25.**

4.25 In this junior high school, tables can be adjusted to whatever position is needed for particular experiments. Oak Grove Junior High School.



4.24 Light, easily moved tables can be ideal when used in conjunction with service islands. Thomas Jefferson High School.

Too often tables are selected for their appearance rather than for their functional value. Most science areas would benefit from having one or two older tables with wooden tops into which nails could be driven and on which various mock-ups or assemblies could be installed without regard to damaging the top of the table.

Another useful feature in a science area is to have a large wooden beam suspended from the ceiling. A variety of items used in experiments and demonstrations can be attached to such a beam. Although we observed many demonstration materials attached to the ceiling in science rooms, we have not observed any facility where this kind of work was planned for by the use of ceiling beams or similar functional structures.

Stone-top tables continue to be among the best in resisting damage from acids or strong alkalies, but massive tables or benches with stone tops tremendously limit laboratory flexibility. A few such tables might be arranged at wall locations, but we do not recommend them for general laboratory purposes. New composition materials are also damage resisting. Long, stable tables for "motion" experiments are needed in physics labs, especially if floors are carpeted. In all laboratory areas some tables with square edges should be used, for it is difficult to clamp apparatus to tables that have beveled edges. Again, a mix of table types may allow for maximum flexibility at minimum cost.

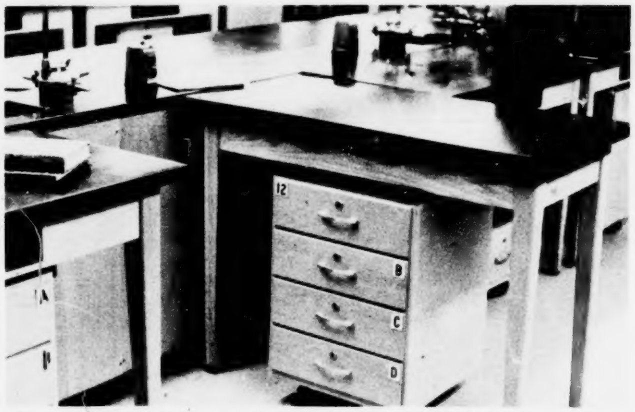
In the previous section on walls we described some of the kinds of furnishings that might be used to separate space. We would strongly recommend the use of various kinds of rolling cabinets, movable chalkboards and bulletin boards, and other furnishings that allow both for functional storage and flexibility in the use of space. Figures 4.16 and 4.17 also show some of the kinds of units that can be useful for storage as well as for dividing space.

Wall cabinets have commonly been used in science laboratories, but with few exceptions, we do not recommend wall cabinets. Instead, inexpensive cabinets in central storage areas can provide the combination of ample storage space at low cost and easy access to wide varieties of materials needed for individualized study. Additional information on storage facilities is provided in Chapter 5.

Massive laboratory units of the type shown in Figures **3.1** and **4.26** cannot be recommended. In schools where we observed this kind of furniture, it is used only occasionally and could easily be replaced by furniture with much greater flexibility. Teachers or architects have too often installed such furniture simply because this was the type familiar to them. Not only is this furniture comparatively expensive, but it severely restricts flexibility in the use of space and in the kinds of activities that can be conducted in a given area.

Where fixed laboratory benches must be installed, we urge the consideration of complementary rolling cabinets such as those shown in Figure **4.27**. These cabinets provide an acceptable compromise between flexibility in the use of a given laboratory space and the need for storage of a variety of materials as the use for a given space changes.

4.26 Large, massive laboratory tables such as this are of limited use and tremendously limit flexibility. This kind of laboratory table cannot be recommended.



4.27 Rolling cabinets such as the one shown here provide more convenient storage of materials than do wall-mounted cabinets. The rolling unit can be rolled to the stockroom-preparation area when new materials are needed. Munster High School.

Room Furnishings

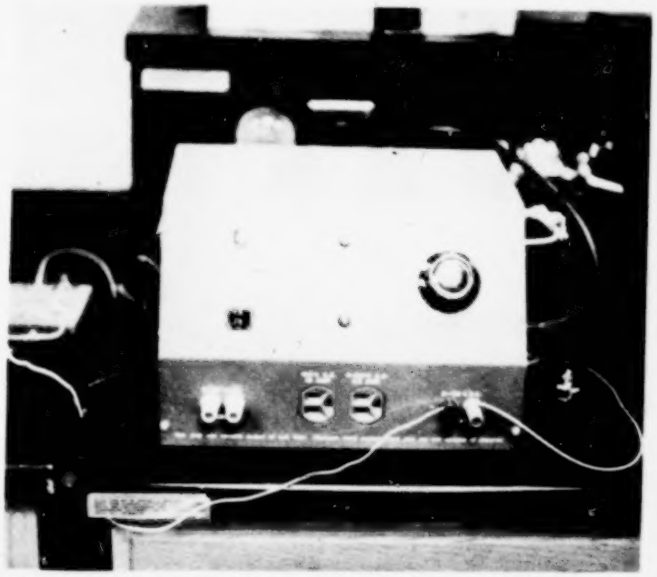
Some of the more serious errors in planning laboratory facilities are in the types of sinks selected. As a rule, pot type sinks (common in some chemistry facilities) are essentially useless. Too often the drains in these sinks become plugged up with paper or other debris, and the unit can serve few functions other than draining water from a distillation apparatus. It is usually desirable to have sinks large enough that a dissecting tray or other materials can easily be handled in them. With few exceptions, sinks smaller than 12 inches square should not be considered. There should be at least one sink in the laboratory area large enough for washing trays or other objects. A preparation-room sink of 24 by 40 inches, with adjacent drainboards, can be a technician's dream. Usually with individualized instruction, fewer sinks are needed, for students are performing experiments which require sink areas at different times.

Garbage disposal units are very functional, but some schools find it necessary to have these only in areas with limited student access.

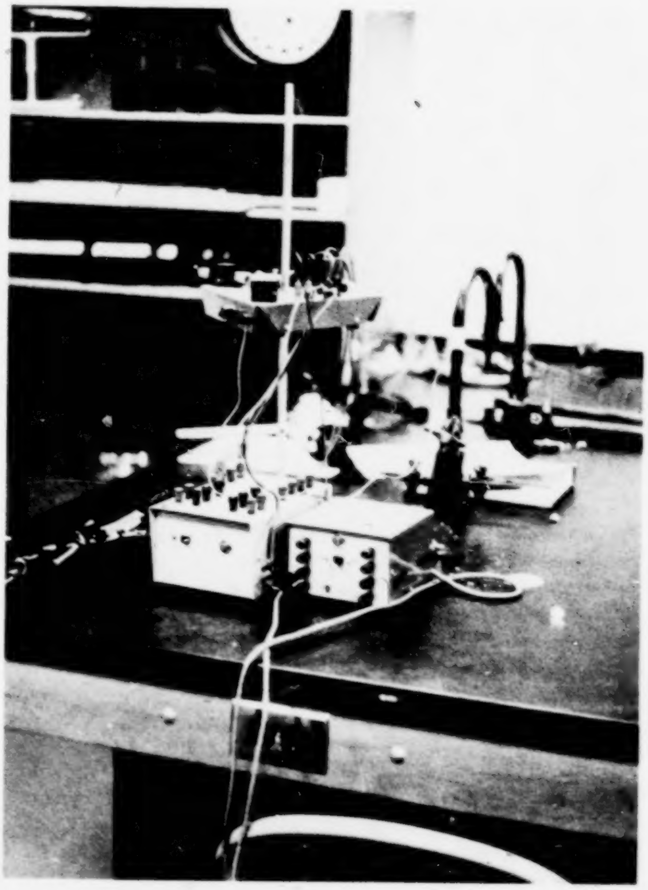
An expensive feature that we do not recommend is the wall-panel power supply found in some physical science laboratories. These expensive wall panels and associated wiring cost much more than the necessary number of portable power supplies. Moreover, there may be undesirable fluctuations in current when a wall panel supply is used. Some physics teachers commented that the wall panel was just a waste of money. In some laboratories, the wall panel was wired to a single voltage, and other voltages were provided through the use of portable power supplies.

In most schools visited where permanent power supply panels were installed in walls, most of the experiments with varying voltage were done using portable power supplies. With the portable power supply, each student can regulate the instrument and can move it to whatever laboratory space is needed for his work. Figures **4.28** and **4.29** illustrate some power supply units. The latter unit has the advantage that it never gets lost, but some flexibility in use is lost.

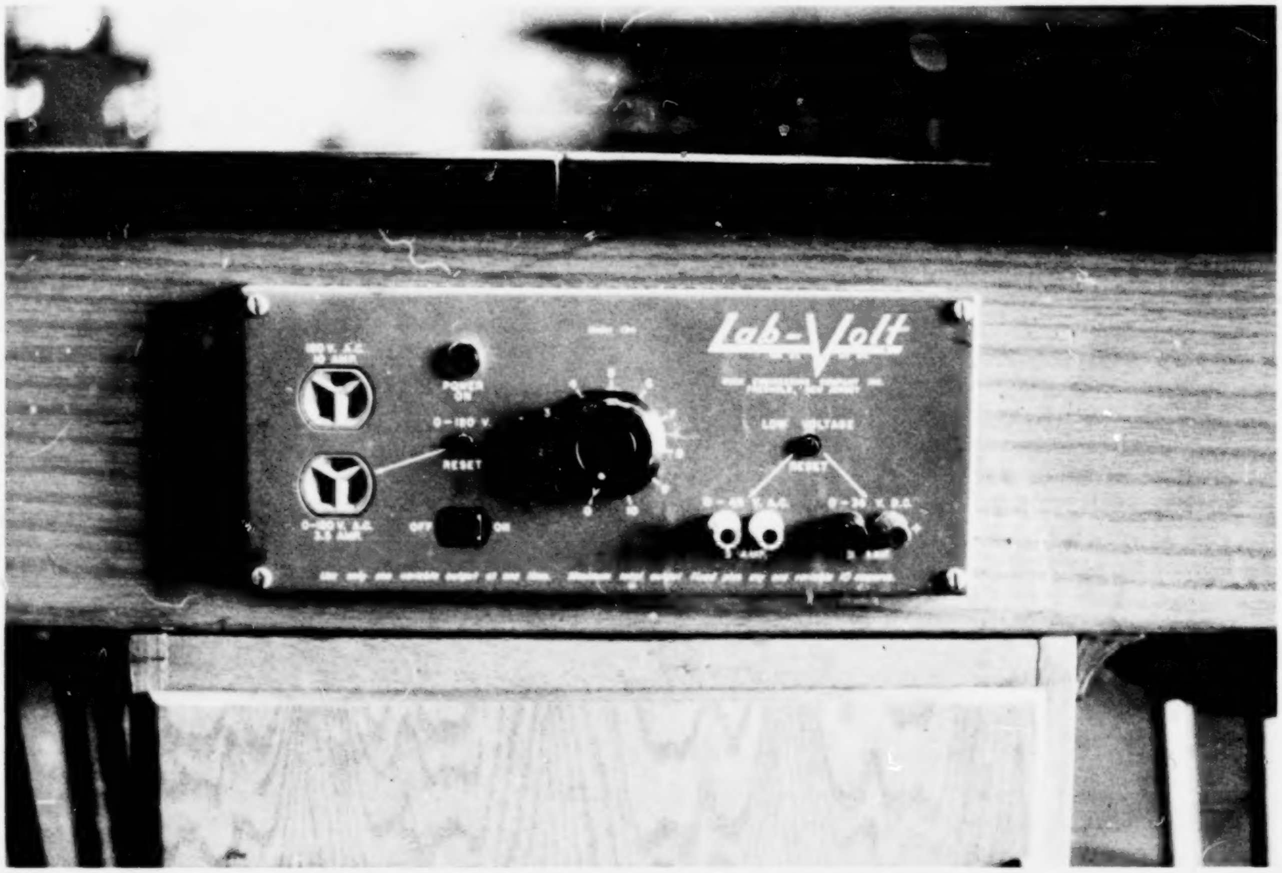
Fire extinguishers, safety showers, fume hoods, and other special furnishings must be considered in planning room furnishings. Additional information on safety items will be provided later in this chapter.



4.28 The two types of portable supply units shown here can be used in a wide variety of individual experiments or small group demonstrations.



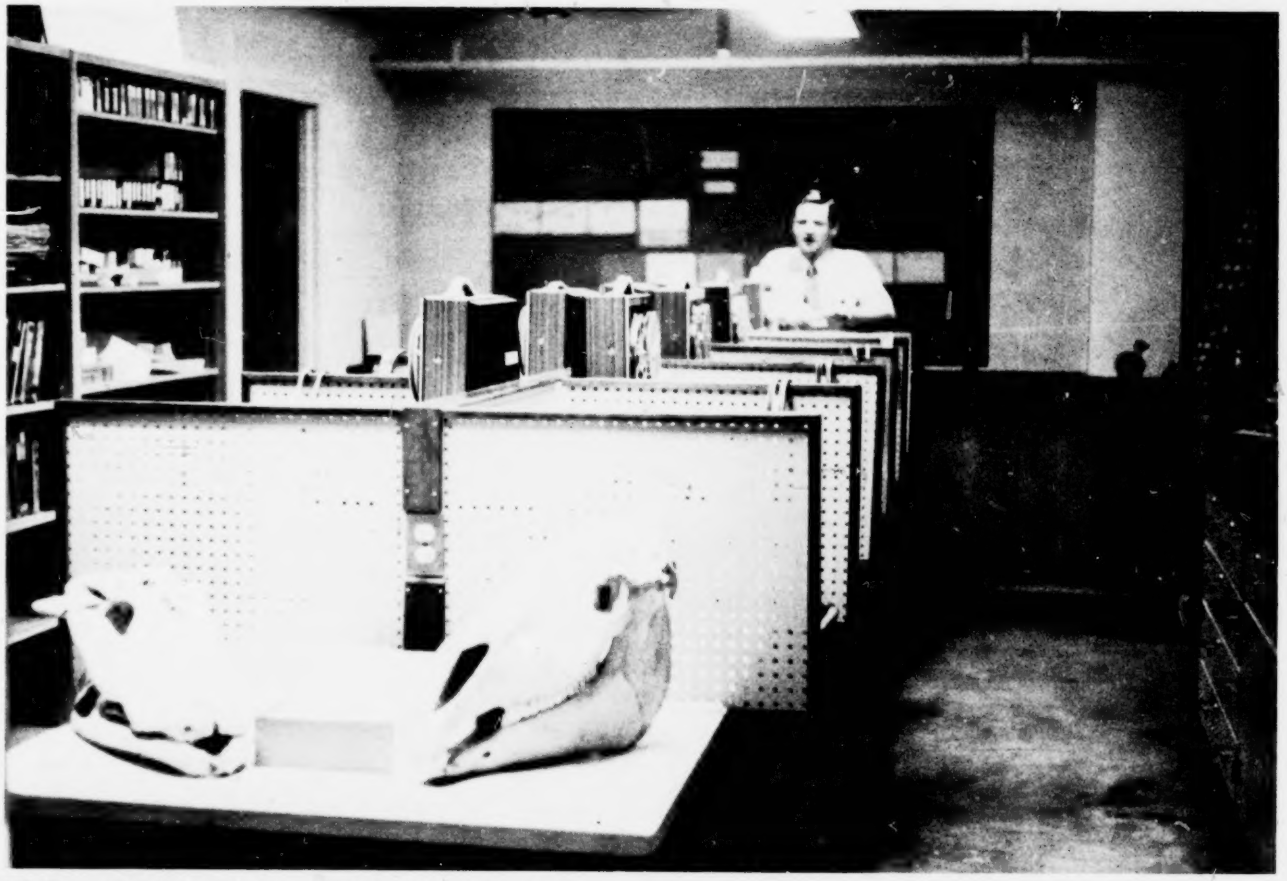
In Part 1 we stressed how the planning of facilities greatly affects the ease with which new kinds of programs can be introduced and the extent to which cooperative activities between students and staff can be facilitated. In the planning or rearranging of room furnishings, teachers and architects too often have planned for a single use for a given space. This has often proved to be unfortunate with the extent of program changes that have occurred in the past ten years. We believe that program changes in the future will be more frequent and more radical. Therefore, the selection of expensive room furnishings designed largely for single-purpose laboratory use must be viewed as an extravagance. Although certain advantages may accrue for a few years, in all probability these furnishings will provide serious limitations to programs in the future. School boards and administrators never welcome the news that expensive laboratory furnishings installed when a facility was built no longer serve the purposes of the teachers and need to be modified or replaced. Since room furnishings are usually purchased from the same bond issue as that obtained for construction costs, expensive furnishings are sometimes installed because dollars are available and not as a result of careful planning for flexibility in future use. The installation of massive, fixed laboratory furniture can be three to four times as expensive as equally functional, but highly flexible configurations of laboratory islands and movable tables. Moreover, as programs and needs change, new furnishings can be added in a highly complementary fashion and will not necessitate a complete overhaul of furnishings in the room. We have found in conversations with teachers that they would like to change part of their facilities, but this would require the removal of relatively new, expensive laboratory furnishings. They know that the administration would look unfavorably on paying for the costs of removing expensive furniture in addition to purchasing the new furnishings. In short, these teachers are stuck with what they have.



4.29 The power supply unit attached to this laboratory bench is inexpensive, but adequate when fixed power supply units are desired.

Room Furnishings

Many readers of this report will be considering alternative uses of space rather than the design of new space and new furnishings. In this connection, we have seen some excellent examples of how old furniture could be used in new ways. When space is used in a highly flexible manner, and areas are divided by temporary partitions and various types of cabinets, it no longer becomes imperative to have all furnishings in a room similar in appearance. Old tables can serve as an excellent base for a series of carrel units, as shown in Figure **4.30**. An old laboratory bench might make a fine work table where students can saw or hammer as they design apparatus for experiments or demonstrations. Again, we would stress the importance of functional and flexible use as the criterion of value for room furnishings. A laboratory room with an array of experiments or demonstrations assembled on various kinds of furnishings would have far more appeal to parents on the occasion of an open house than rows of polished bench tops.



4.30 The carrel units shown here are attached to an old table which had previously been discarded. John Burroughs School.

Facilities for Independent Study, Group Study, and Technologically Mediated Study

Furnishings such as those recommended in the previous section permit flexibility for the establishment of independent study areas. An increasing trend in science programs is the use of some technological support in teaching, often in association with carrel units. There is almost no limit to the variety of carrels that are being used, and many kinds are being marketed by commercial organizations. For the most part, carrels in the $100 to $150 price range may be attractive, but they often are limited in their versatility and are unnecessarily expensive. Most teachers have found that some form of homemade carrel constructed with the aid of shop students very adequately serves the purposes of the science program. Figures **4.31**-**4.33** show some of the homemade carrels observed in our study. We recommend that the majority of carrels be larger than the common 30-inch width, thus allowing for two students to work together in a carrel space. Connections for head sets for student listening should allow two or three students to plug in at a single carrel space. Most teachers who have encouraged two students to work together in carrels on various science facilities have found this to be not only well received by the students but productive in terms of work. If criterion-referenced evaluation is used, student cooperation becomes a team effort to achieve mastery of a given set of learning objectives. Every effort should be made to encourage this type of positive relationship between students.

4.31 These homemade carrels serve all science classes in the remodeled laboratories of this high school. L. E. Berger Middle School.

Facilities for Independent Study, Group Study,

Some characteristics to consider in constructing carrels are:

- The wall of the carrel should be sturdy enough to lean on, and the table used should be strong enough to sit on.

- A shelf should be provided across the back of the carrel. Whenever possible, this shelf should be easily adjustable to different heights. The shelf also serves as a shield from overhead lights, permitting projection of slides or loop films against the back surface.

- Pegboard makes excellent walls, for it allows use of hanging racks and other devices. This material is also light enough to make the carrel portable.

- Portable carrels must be designed so that they can be folded and stored conveniently. The carrels shown in Figure **4.32** are easily disassembled and folded for storage or for transfer from room to room. When portable carrels are used, the walls should be such that they will not slide off the table, but they should be easily removable from the table.

- Sufficient grounded electric outlets should be available in the carrel with an adequate length of extension cord. One kind of grounded outlet is shown in Figure **4.33.**

- Most carrels should be designed so that two students can use the space together. Some carrels should be reserved for one-student activity. A carrel 42 to 48 inches in width and 20 to 24 inches in depth would be adequate for two-student use, whereas a 30- to 36-inch width usually is sufficient for one-student use.

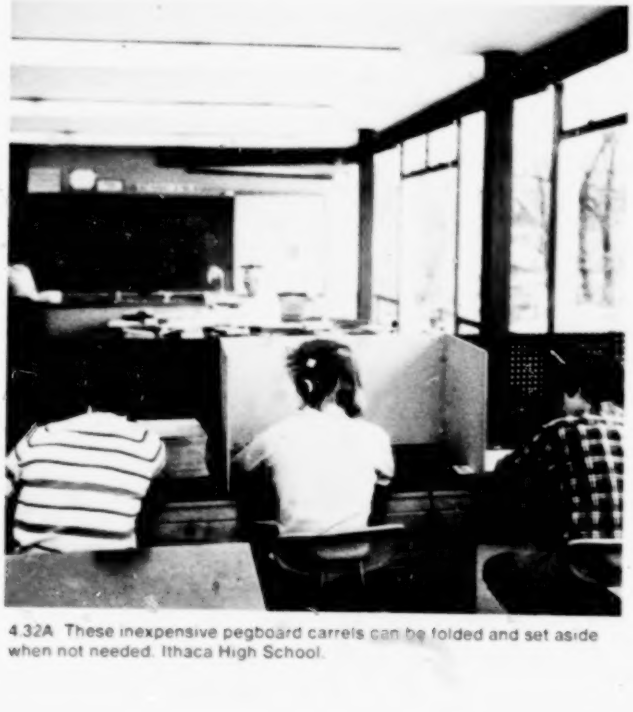
- Whenever feasible, all surfaces should be washable. Carrels made from heavy cardboard are usually so inexpensive that they can be discarded when their appearance is too unsightly.

- Some carrels might be designed with high walls and backs for use with special demonstrations or experiments. These carrels will be most useful if the wall materials are pegboard and allow for attachment of various objects to the surface.

- Carrels should be painted in light colors because students object to dark colors.

It is not necessary, of course, to have carrel units in order to individualize instruction. In fact, some students object to the visual isolation even when they are working with tape recorders and other equipment. Consideration should be given to students who wish to do their individual study activities at tables or at other locations in the room.

4.32 Cardboard carrels are homemade and very inexpensive. Jamesville-Dewitt Central School.



4.32A These inexpensive pegboard carrels can be folded and set aside when not needed. Ithaca High School.

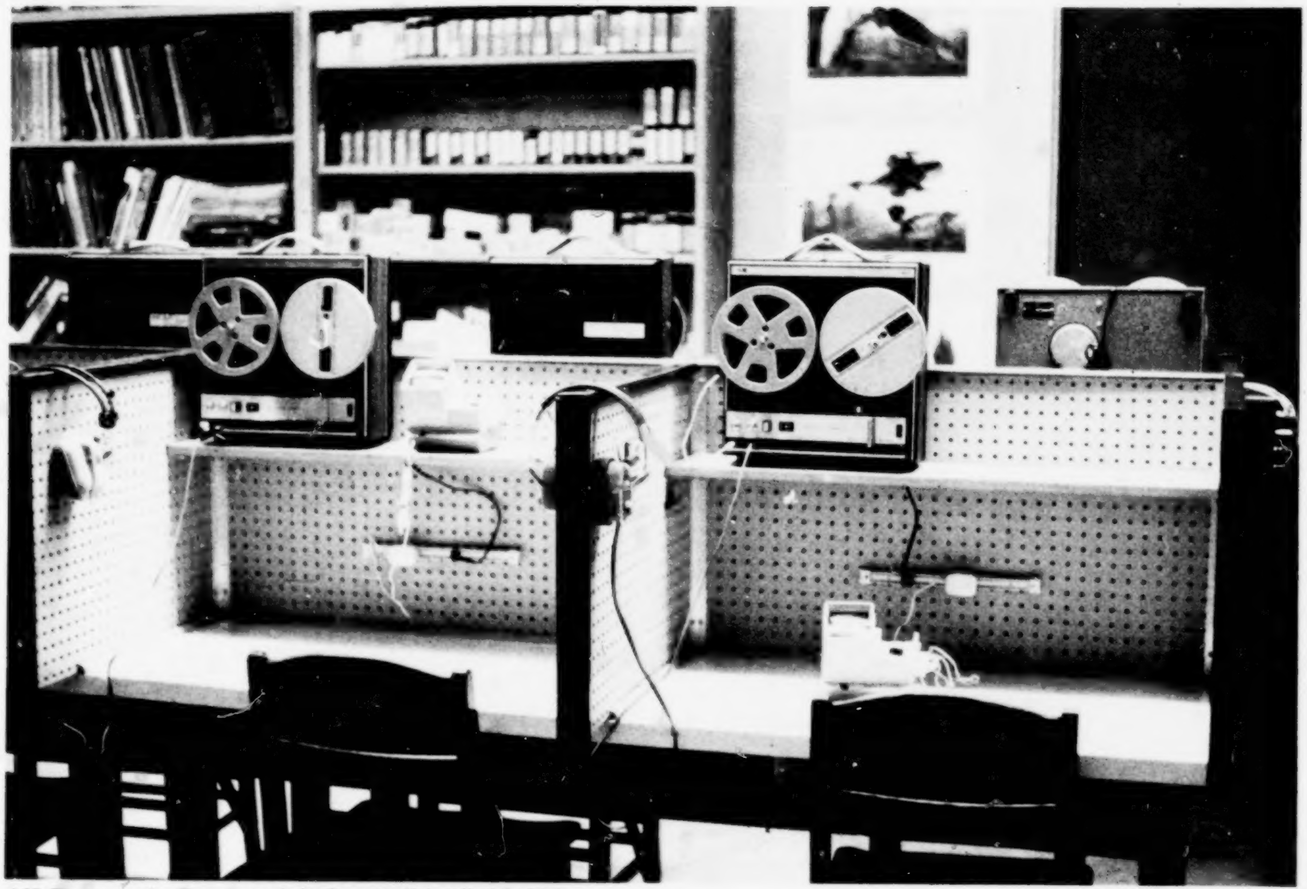
and Technologically Mediated Study

We urge that teachers experiment with the design of various kinds of carrel units and other arrangements for individualized study. It would be well to enlist the cooperation of students in the design and construction of learning spaces. In many cases, students will willingly contribute time and effort for the construction of carrels or other separating surfaces, thus reducing the costs for developing study environments to an absolute minimum. When shop facilities are available to students, student-made carrels can be attractive, functional, and inexpensive.

Some facilities have been observed where controls for electronic equipment are located in drawers beneath table surfaces and no carrels are used, as shown in Figure **4.34**.

Special kinds of carrels are often used in conjunction with dial-access or other retrieval systems. These are discussed further in Chapter 5.

4.34 Controls for tape recorders in this laboratory are located in a drawer of the laboratory bench. Carrel units were not found to be necessary in this laboratory facility using individualized instruction. Meramac Community College.



4.33 These carrel units were made by the custodial staff of the high school. John Burroughs School.

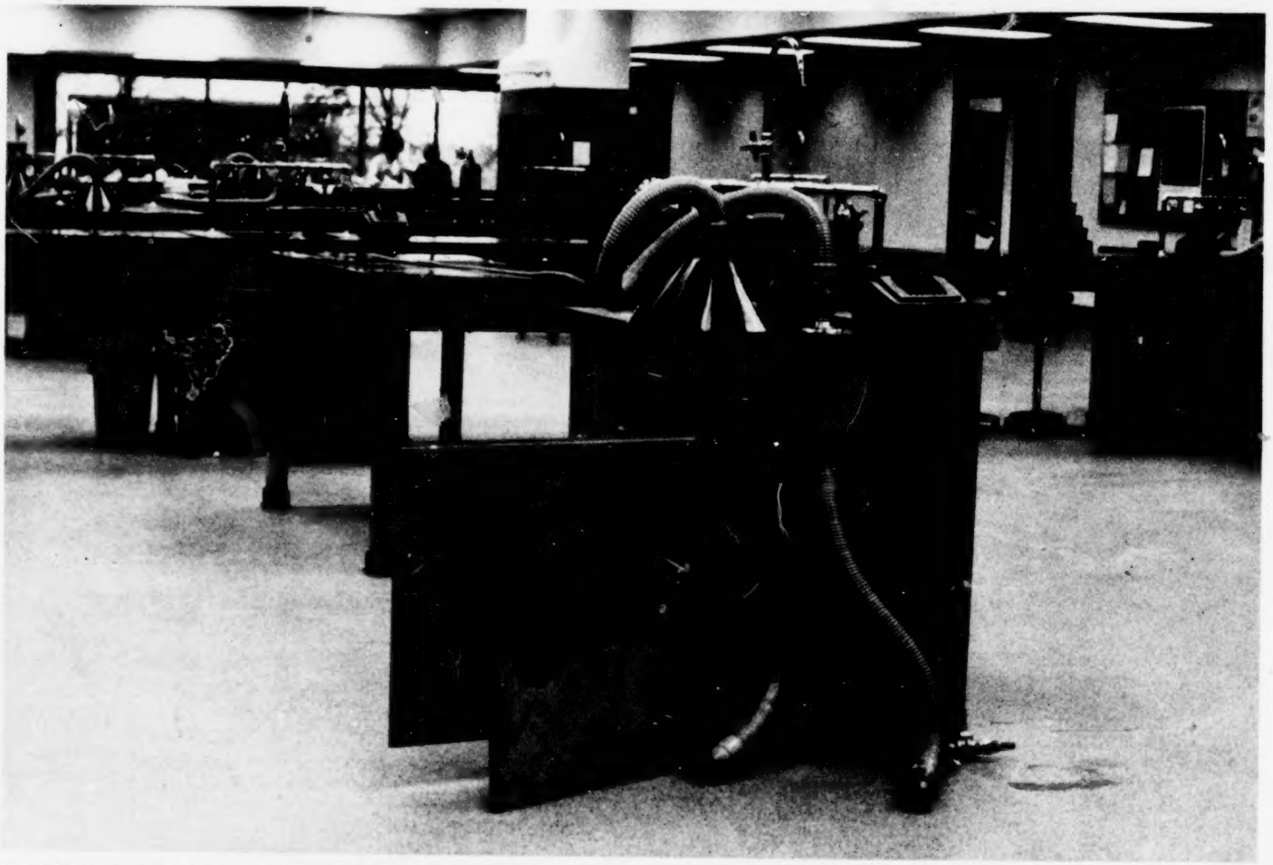
Utilities

The most flexible arrangements for utilities in a serviced work area are those found in portable service islands with plug-in water, drainage, electricity, fume hood, intercom, and the like. Portable service islands were discussed in the section on internal walls.

Utilities for atmospheric control include air-conditioning and heating ducts. Air-conditioning equipment is becoming standard in most parts of the country. Any school which is now built without air conditioning would probably be considered immediately obsolete. The trend is to use the school buildings year round, and in most parts of the country, air conditioning would be a necessity for this type of use. It is suggested that a student's learning efficiency goes up 25 to 30 percent in an air-conditioned classroom.

Ventilation and exhaust facilities are of critical importance in the general laboratory area. Heat from burners, excess humidity caused by boiling liquids, transpiration from plants, fumes from chemicals, and odors from preserved and fresh specimens are often present. If the air in the room is not changed continuously, the atmosphere will not be conducive to learning. At times it may become completely unbearable. It is, therefore, imperative that the exhaust system have ample capacity and that it be operable at all times. In addition to provisions for normal ventilation, it is recommended that exhaust fans be independent of the main school ventilation system. Fumes which originate in the science complex should not be recirculated through the building nor vented to the outside near any air intakes. [19, p. 85]

4.35 Portable hoods such as this can be adequate for most purposes, providing that sufficient vacuum power is available and vented independently of the school's air-conditioning system. Munster High School.



4.36 This laboratory island can be unplugged and moved away in minutes. Connections are available for electricity, water, an intercom unit, and a fume hood. Most building codes would not permit detachable gas lines, and no gas service is provided here. St. Andrews Presbyterian College.

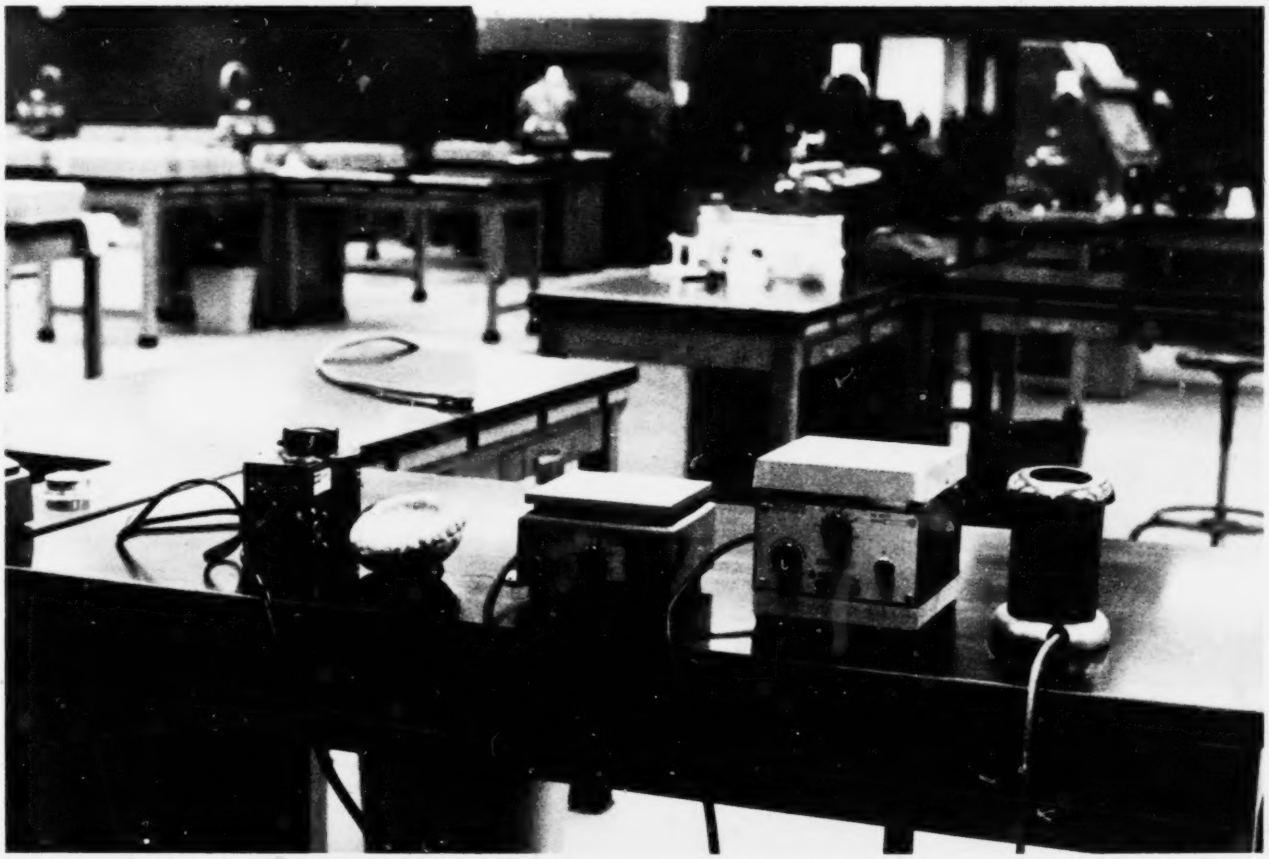
Figure **4.35** shows a portable hood. These hoods are useful pieces of equipment if they have adequate ventilation. Figure **4.36** shows a portable service island or utility core which contains "plug-in" water, electricity, intercom, and also a small fume hood.

Because of building code regulations, none of these portable service islands with plug-in utilities contains gas for Bunsen burners. However, the science teachers who use the portable islands find that they can do very well without the traditional Bunsen burners.

Bottled butane burners along with water baths and many types of electric heat sources can serve all science disciplines. At first thought, chemistry teachers may insist that there is a definite need for the traditional Bunsen burner. The Bunsen burner and necessary gas lines are a source of great inflexibility in science laboratories. Some schools are seen in which only the chemistry area is burdened with massive, fixed furniture, and all this is necessitated by the pipes which serve the Bunsen burners. Figure **4.37** shows some electric heating units that may substitute for Bunsen burners. From left to right is a type of rheostat (a heating "nest" used for boiling flasks), a hot plate, a magnetic stirring hot plate, and a heater into which can be inserted test tubes of various sizes. We have found that all situations calling for a heat source can be met without the use of a Bunsen burner. By doing away with the gas pipes, science facilities may greatly increase their flexibility.

Seven criteria for choosing a heating and air-conditioning system for a school are: (1) temperature control; (2) humidity control; (3) odor control; (4) noise control; (5) draft-free uniform air distribution; (6) first cost; and (7) operating cost.

These criteria are discussed in relation to the common types of heating and air-conditioning systems used by schools in several of the references included in the annotated bibliography. Appendix 3 lists some specific user criteria for the atmospheric conditions in science laboratories, stock rooms, resource and study rooms, and growing rooms.



4.37 Electric heating units such as those shown here can substitute for the traditional Bunsen burner. When gas lines are not included in laboratory islands, much flexibility is retained. Those schools using these kinds of heating units have found them completely satisfactory. St. Andrews Presbyterian College.

Utilities

There are two particular problems of controlling atmospheric conditions in large open rooms: heating of the space and achieving flexibility to meet anticipated changes in the use of the space. We observed several solutions to these problems. A heating system for an open-plan middle school was devised to use electric radiant heating panels in the ceiling and the warmth from students, staff, and lighting equipment to heat the school [20]. 300 radiant ceiling panels of 500 watts each were installed in the T-bar ceiling around the perimeter of the academic and resource center. In addition, 30 units of 750 watts each were mounted in the locker rooms.

The second problem is that in larger open spaces, the particular use to which a certain area is put may change from year to year or month to month, and the lighting arrangements, air-conditioning controls, and the like should be equally adaptable.

One way to build in adaptable services was developed by the School Construction Systems Development (SCSD) project. [13] Here, all of the mechanical subsystems including wiring, lighting, TV conduits, air ducts, and plumbing were interlaced in a 36-inch space between the roof deck and ceiling — a space called the "service sandwich." This service sandwich contained those atmospheric control ducts which were relocatable and thus could be rearranged (these changes could be done over a weekend) to supply a certain area with more or less heated or cooled air. [21]

Figure **4.7** shows a seminar room formed by demountable walls in a large open area. Figure **4.9** is a rear view of that open area. The lighting has been rearranged so that one switch in the seminar room controls the light panels immediately above it. The air-conditioning ducts can also be relocated so as to improve the ventilation in the smaller room.

The open space in some schools planned and built by the SCSD project contained open spaces of 90 to 110 feet long with no weight-supporting walls. However, there were demountable partitions which divided up the space and gave the schools maximum flexibility in providing for future changes in school needs and for unforeseeable developments in school programs. But there is not much use in being able to change partitions around if one cannot also change the lighting arrangements, as well as the air-conditioning systems and its controls. . . . As finally designed, the air-conditioning outlets, with flexible ducts, may be moved to almost any line on the five-foot grid, and independent controls may be provided for up to eight spaces in each module of 3,600 square feet. Lights — of several varieties — are interchangeable with ceiling panels. [22]

The specifications for the service sandwich and the modular construction of these California schools can be found in *SCSD: The Project and The Schools*, listed in the bibliography.

The point being made is that there are materials and technology which can be used to build schools with mechanical subsystems such as lighting and air conditioning which can be easily changed to meet the evolving uses to which a space may be put in future years. A school need not design its program around internal walls or the distribution of air ducts. These mechanical features of the building can be reorganized from time to time as the instructional program evolves.

We have cited a number of references in this section that provide additional information on the design of school facilities. Since new materials and new technology are continuously emerging, it is important to check recent journals, such as those included in the annotated bibliography, for new information on design possibilities. Although many architects will be familiar with recent literature, science teachers and other staff members will be in a position to discuss design alternatives more intelligently if some homework is done in appropriate journals. Teachers planning new facilities should not assume that architects will be familiar with all possible options that may be considered in the design of flexible, future-oriented science facilities.

Total Energy: Electricity, Heating, & Air Conditioning

The energy requirements of modern schools are rapidly increasing. Many schools will be open 12 months a year, and air conditioning for most of them will be a necessity rather than a luxury. Evening classes, increased use of technologically mediated instruction, and multifunctional buildings all point to the fact that schools will be using more and more power. In many parts of the country, the cost of obtaining electric energy from power companies is high and increasing. Many shopping centers, industrial plants, commercial buildings, and some schools have installed equipment in their buildings to generate their own electric energy. This technology is called "Total Energy" and has been described in *Technical Report 2* from the Educational Facilities Laboratories (EFL).

The idea of total energy is deceptively simple: its ramifications are fascinating. The school or college installs its own electric generating system, then captures the system's "waste heat," applying it for steam or hot water, and uses this by-product for heating, air conditioning, and domestic hot water. In appropriate situations, fuel costs to power the generating system are less than the cost of electricity from a public utility. And the heat supplied by the recovery systems represents fuel that would otherwise have to be paid for. [23, p. 9]

In the Educational Facilities Laboratory's report is a description of the cost data from two schools. The Msgr. O'Rafferty High School in Lansing, Michigan, has shown energy cost savings of between $8,000 and $10,000 annually. O'Rafferty's total-energy system cost $80,000 more than a conventional system to install, but this excess will be paid for in 10 years. [24] The McAllen High School in McAllen, Texas, conducted a feasibility study prior to construction and determined that the electric power bill would come to $64,474 per year if the energy were purchased from a power company. The school installed a total-energy system, and its fuel bill for the first 18 months averaged $13,280 per year. The school had saved $51,200 per year and could expect to amortize all of the total-energy equipment in five years, after which time (except for maintenance costs and increases in fuel costs) the school would be saving a clear $51,200 each year at the same rate of energy use. [25]

The Greater Muskegon (Michigan) Catholic Central High School installed a natural-gas-powered total-energy system. "By generating power instead of buying it, the high school has halved its average electricity cost from 2.52 cents to 1.26 cents per kilowatt hour, saving more than $3,600 on power alone during the first six months on total energy." [26, p. 35]

Schools which have operated on a total-energy plan report considerable savings in yearly operating costs. In order for a total-energy plan to be economical: (1) There should be a fairly constant demand for electric power over most of the day and the year. (2) Demands for heat and air conditioning should occur simultaneously with the demand for electricity. (3) Gas or liquid fuel rates in the area should be low enough to compete with local electric rates. The installation cost for a total-energy system will increase the construction costs of a school by 2 to 5 percent, but this energy system will pay for itself in a few years. [27]

Guidelines for a feasibility study, which should be conducted as a school is contemplating a total-energy system, are listed in the previously mentioned EFL report, *Total Energy*. [28]

A point which cannot be overemphasized in relation to the total-energy system or any other component of the mechanical systems of a school is the relation of initial cost and operating costs. For the total-energy system the initial costs include the purchase and installation of equipment. The operating costs include the price of fuel and the labor and material costs of maintenance. Arrangements with the equipment manufacturer should include a multiyear maintenance contract. If a company is bidding on equipment plus upkeep (air-conditioning system, fume hoods, total-energy system, for example), it will make that equipment much more durable than if it is bidding on the equipment alone. Even though the school will have to pay more initially for a contract that includes equipment and maintenance, it will have bought more durable equipment, and, within a few years, the school will have made up the difference and probably be saving money because of cheaper operating costs.

Two other points should be mentioned concerning the total-energy system concept. First, in a positive vein, it may be wise for a community to have available a self-sufficient building which would be very useful in case of some emergency, such as a widespread power failure. Second, on the negative side, the more places there are which generate their own electricity from a fuel such as natural gas, the more potential sources of pollution there are. It is important to become aware of potential environmental hazards and use this information in making decisions.

Safety

Welfare of students and teachers is a first consideration in the design of science facilities. This must be basic and superordinate to any other consideration. Factors related to safety specifications include location of science facilities in the building, fume-hood specifications, building codes, floor coverings, use of areas for preparation and student projects, emergency equipment, and special arrangements for handicapped students.

Location of science facilities in the building. Some fumes produced in the science laboratories are more dense than the normal atmosphere. When these fumes are produced on an upper floor, they have a tendency to move down stairways to lower levels; therefore, these laboratories (usually associated with chemistry) should be located on the lowest level available.

Fume-hood specifications. Fume hoods equipped with adequate exhaust fans can alleviate many of the fume and odor problems. The Metropolitan Toronto School Board Study of Educational Facilities suggests that:

> "A few fume hoods for students are required, with a capacity great enough to draw all fumes from a distance of six inches from the orifice, when all hoods are being used at once. There should be a well ventilated storage cupboard which is connected to the exhaust system. This would be used for supplies having corrosive fumes; it needs a resistant interior and fittings. Such a storage cupboard is often located beneath a working or demonstration fume cupboard." [29, p. 85]

Building codes. An excellent article by Lewy Olfson entitled "Building Codes: Something Needs to Be Done" [30] described the obstacles which some regulations impose on innovation. Most (if not all) building codes were based on the "egg crate" idea of the school building. Some general problems associated with building codes are discussed by James Wright in a 1971 article in the *Scientific American*. [31] It is argued that codes need to specify performance standards rather than structural details; this would allow for new technology and flexibility of design to meet these standards.

Internal walls have fire ratings, and there is often pressure to install floor-to-ceiling walls to decrease the fire hazards to the children. This is clearly a motive of paramount importance, but fire safety can be achieved in other ways than by using walls. Heat-sensing alarms and ceiling sprinkler systems can often be substituted for walls to meet fire-safety considerations. Many building codes still state how objectives (such as safety from fire) are to be met instead of stating what the objectives are. The purpose of fire codes is to assure that the school can be cleared of children in *x* number of seconds or minutes. Architects should be free to determine what kind of designs will meet these safety standards.

The evolving trends in facilities include the use of portable service islands with plug-in utilities. (These islands are not equipped with piped gas.) One school system visited had recently built three new schools. The science staff tried to include the table service stations in the facilities. It had no success with the first school, and large fixed furniture was installed. A few years later when the second and third schools were built, the inspectors were persuaded to allow service islands which could be moved by a licensed plumber. A new school is being planned, and the science staff is confident that the inspectors will now allow plug-in utilities. Building codes are changeable and are changing. Architects and contractors need to explore existing code limitations that apply to new science facilities.

Also in the area of room furnishings, the codes of some areas will not allow movable cabinets. The concern is that this furniture, which has been available and used elsewhere for years, would easily tip over and dump its contents when bumped or moved. Again, the building codes state how the objectives are to be met rather than stating specifications of the objectives. A revised code might state that a piece of furniture (such as a cabinet of shelves) shall not tip over when a force of magnitude *x* is applied at a certain point on that piece of equipment.

A previous discussion of walls included a list of their functions. Since floor-to-ceiling walls do limit the flexible use of space, suggestions were made regarding types of furniture, carpeting, and other furnishings which would better serve the functions now served by many walls and would increase the flexible use of space. Only a few types of desirable cabinetry which can serve as wall substitutes are now available. However, the market for this type of furniture will be expanding, and this demand will stimulate the design of better wall substitutes. Some building codes may have to be altered to allow for this totally new type of school furniture.

Floors. This study had suggested very strongly that carpeting is now a necessity, including its use on laboratory floors. However, some areas such as those in the immediate vicinity of an outside door and other areas of dense traffic should be carpeted in such a way that easy replacement of the carpet is possible when necessary. The use of covered patios or other design arrangements can reduce substantially the amount of dirt carried into front entrances.

Preparation areas and student project areas. As has already been noted, when glass partitions are used forming preparation and project areas, the teacher can more easily supervise activities in adjacent areas. However, this glass must be shatterproof.

Emergency equipment. Occasionally, small fires may occur in the laboratory and extinguishers should be immediately available. [32]

4.38 Students in laboratories should wear goggles and plastic aprons when performing experiments as shown here. Maine Township High School North.

Safety

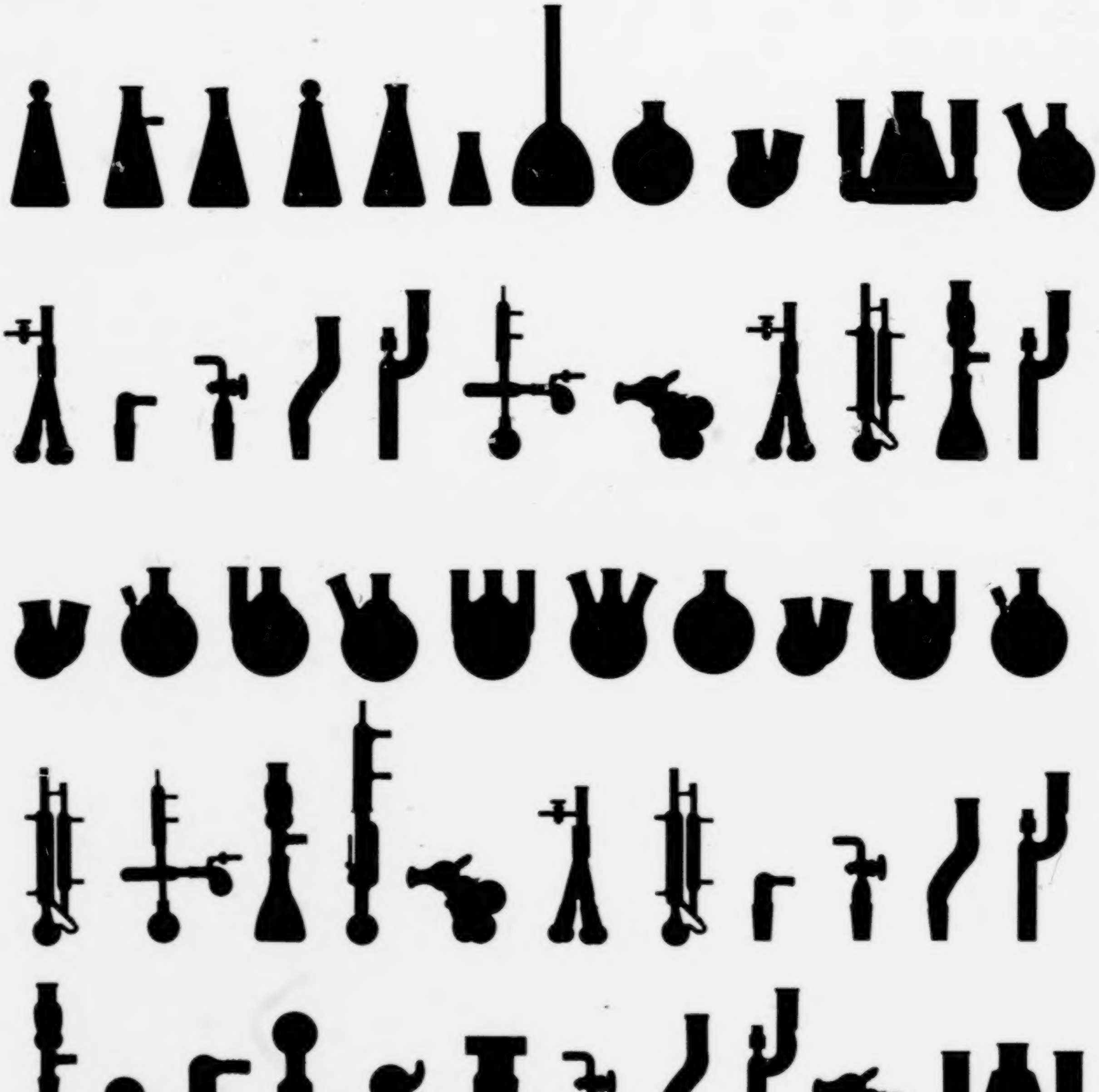
Goggles or some similar equipment must be available to protect eyes of all persons in a certain area, as shown in Figure **4.38.** In a booklet entitled *Science Teaching and the Law* [33], examples of laws regulating the use of eye-protection devices are given. A teacher may even be liable for damage to the eyes of a visitor in certain circumstances. In the many science laboratories visited during this study, very few students, staff, or other persons were seen wearing goggles. Protection of the eyes and plastic aprons should always be required in chemistry work. (Figure **4.38**) Some type of shower and eye bath should be available (see Figure **4.39**). While many of the schools visited did have this equipment, it was most often made inoperative either because the water was turned off at a master valve or because the pull chain was taken off.

How to . . . Provide for Safety in the Science Laboratory [32] discusses additional emergency equipment which is useful, as well as problems such as that of controlling spilled mercury. The *Handbook of Laboratory Safety* [34] is an important publication and should be used by science teachers. John Sulcoski and Grafton Chase in another title in the "How to Do It" series, *How to Use Radioisotopes Safely,* [35], thoroughly discuss procedures and equipment needed for the handling of radioisotopes.

Handicapped students. Some special precautions should be taken for the safety of handicapped students. Some service work area should be low enough to allow a student in a wheelchair to work safely. Similar facilities would be needed in a special project area for that student. Whenever possible, ramps as well as stairways should be provided for easy transportation.

4.39 Conveniently located shower and eye-wash units are a necessary part of science facilities. It is important that floor drains be included when the building is designed. University High School.

Chapter 5



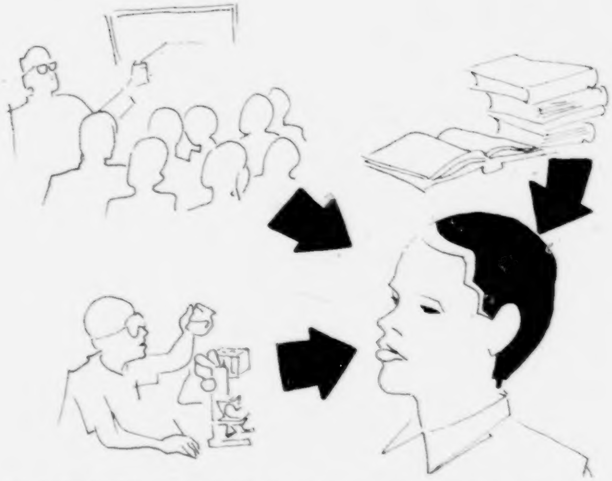
Management of Instructional Materials in the School

To integrate learning of science with other human activities; and to encourage personalization of the instructional program for each student, we need to provide proper management of instructional materials.

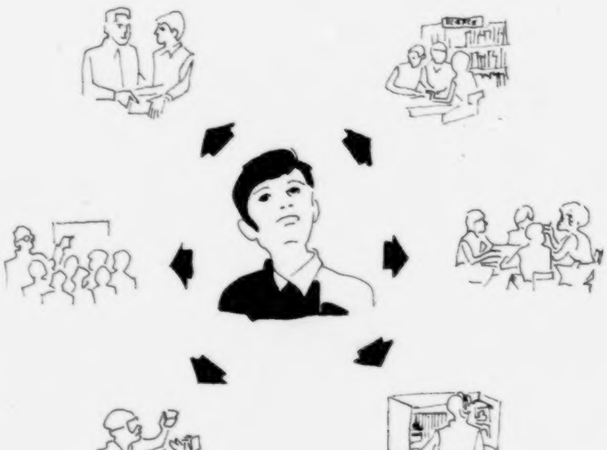
Science study is only one part of the students' school day. Arrangements that will enhance integration of science activities with other school experiences should have positive consequences in students' attitudes and in their success in acquiring knowledge and skills. In this chapter we consider physical arrangements for individualized study space, technological support systems, laboratory materials logistics, and alternative floor plans.

In our description of evolving patterns we indicated that an evident trend observed in schools is toward programs that allow increasing opportunity for variation in the study activities of individual students. Also, students are being given more responsibility for decisions in the selection of study materials. Figure **5.1** shows a model of the traditional approach, where students play a relatively passive role, with much of the information and direction for learning coming from the teacher. Reading assignments and laboratory exercises are a part of this approach, but again the selection and scheduling of these experiences are primarily teacher determined.

Figure **5.2** shows a model for the emerging patterns where students are provided a wider range of instructional resources and are involved in scheduling and selecting learning activities. While these models oversimplify the contrast between traditional and newer approaches to instruction, they may serve as a general scheme for interpreting alternative arrangements for science facilities.



5.1 In the traditional mode of science instruction, the student receives information from the teacher, books, and laboratory experiments. However, the student plays a relatively small part in decisions regarding what materials will be used.



5.2 The emerging pattern of school instruction places the student in an active role, both in the selection of learning materials and in decisions regarding the rate of progress through study units. A wide variety of materials must be available at any given time in this model of instruction.

Libraries and Resource Centers

In the traditional school, a library, as well as large-group study halls, is available to students. However, the use of library and study hall facilities frequently was at scheduled times and not as an integrated part of the science program. Moreover, the library facility was organized primarily for textbook and magazine references, with little audiovisual media or other forms of nonverbal resource material. Virtually every school visited by the study team has expanded its concept of library to include a wide array of learning materials. These new facilities, usually called learning centers or resource centers, may offer students the opportunity to view filmstrips, 8mm loop films, 16mm films, color slides, and a variety of other audiovisual material. Listening stations may be available for playing records or audio tapes that are used in conjunction with other science study materials. Access to printed material is frequently more open than it is in the traditional library. Figures **5.3** and **5.4** show examples of learning centers observed during our study.

5.4 Books, audio tapes, loop films, and other materials are available in this learning center. University High School.

5.3 This modern learning center allows students to work individually or in small groups with several sources of information. Greenwich Senior High School.

In some cases, learning centers are used primarily by students for subjects other than science. In a report entitled "Architectural and Administrative Considerations for Science Teaching" [36] the point was made that there is a very high correlation between the degree to which science students and teachers use media centers and the proximity of these centers to the science facilities. We also observed this pattern. Some of the media centers which were best used by science students were located immediately adjacent to the science laboratory facilities, as shown in Figure **5.5.** In one California school, a separate general learning area for science, surrounded by conventional science laboratories, has become increasingly used by students and teachers. The design of this building, employing modular construction, allowed for expansion of this general learning center as students and staff found increasing value for this area. Although an excellent school media center is available to students, it is in a building separate from the science facility. Therefore, the staff members move large quantities of printed and audiovisual materials to the general learning area of the science facility. Figure **5.6** shows a scene from Oak Grove High School in San Jose, California. The general learning area is carpeted, and students move freely from regions in this area, depending on their specific study activities. Since scheduling is modular, students can arrange for varying lengths of activity in the science facilities, including blocks of time for laboratory work or occasional lecture presentations. This integration of media centers with science activity is a pattern we would very much encourage in the planning of new facilities.

5.5 The learning center shown here is used for science study and is located adjacent to conventional laboratories. Monona Grove High School.

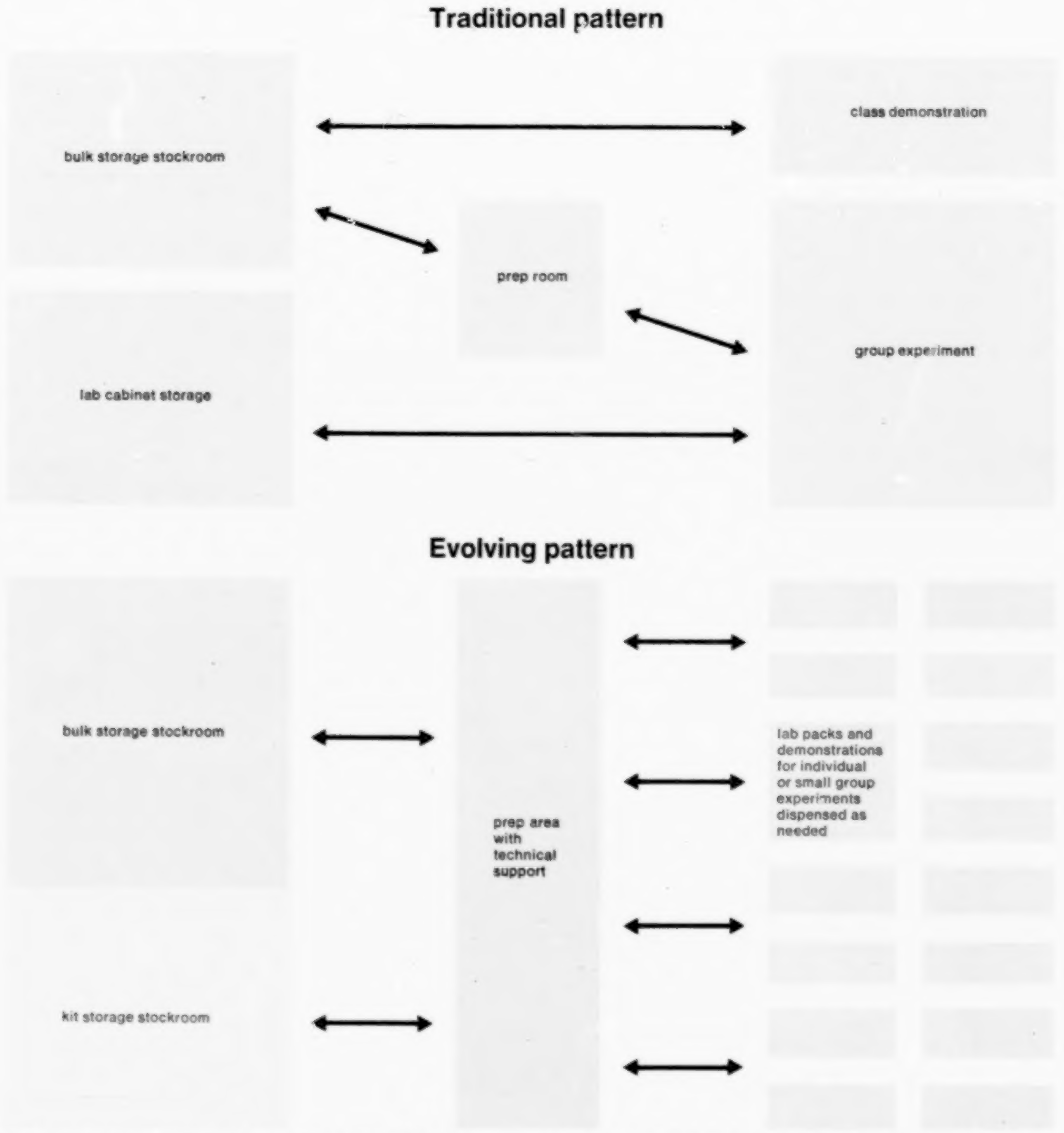
Small study rooms, special project areas, and adequate storage facilities best support the science program when they are available immediately adjacent to science areas.

5.6 This learning center is surrounded by science laboratories and small project rooms. It is used extensively by students and staff for individual and small-group study. Oak Grove High School.

Supply Logistics

Appropriate logistics for the storage and distribution of science materials to students is a critical consideration in planning new or remodeled facilities. This is especially true in regard to providing needed laboratory equipment and supplies to students on individualized schedules.

In Figure **5.7** we illustrate the difference between traditional and newer patterns of material supply. In the traditional pattern, most of the commonly used supplies are stored in drawers or shelves provided in laboratory furniture or attached to walls in laboratory rooms. Some central storage is also used, especially for demonstration materials or for those things used only occasionally during the school year. A preparation room may be a part of the science facilities in a traditional arrangement, but seldom is technical assistance available for the maintenance and distribution of supplies in traditional programs.


Traditional pattern
bulk storage stockroom
class demonstration
prep room
group experiment
lab cabinet storage
Evolving pattern
bulk storage stockroom
kit storage stockroom
prep area with technical support
lab packs and demonstrations for individual or small group experiments dispensed as needed

5.7 The traditional pattern of materials logistics, shown at the top, has materials stored in laboratory cabinets and wall cabinets, with bulk storage of some supplies and demonstration materials. Preparation rooms are sometimes absent and material is transferred directly from bulk storage to laboratory cabinets, with preparations designed for group work. In the evolving pattern, almost all materials are maintained in a stockroom and distributed to students according to their needs. A large preparation area with part-time or full-time technicians is a common feature in this type of materials logistics.

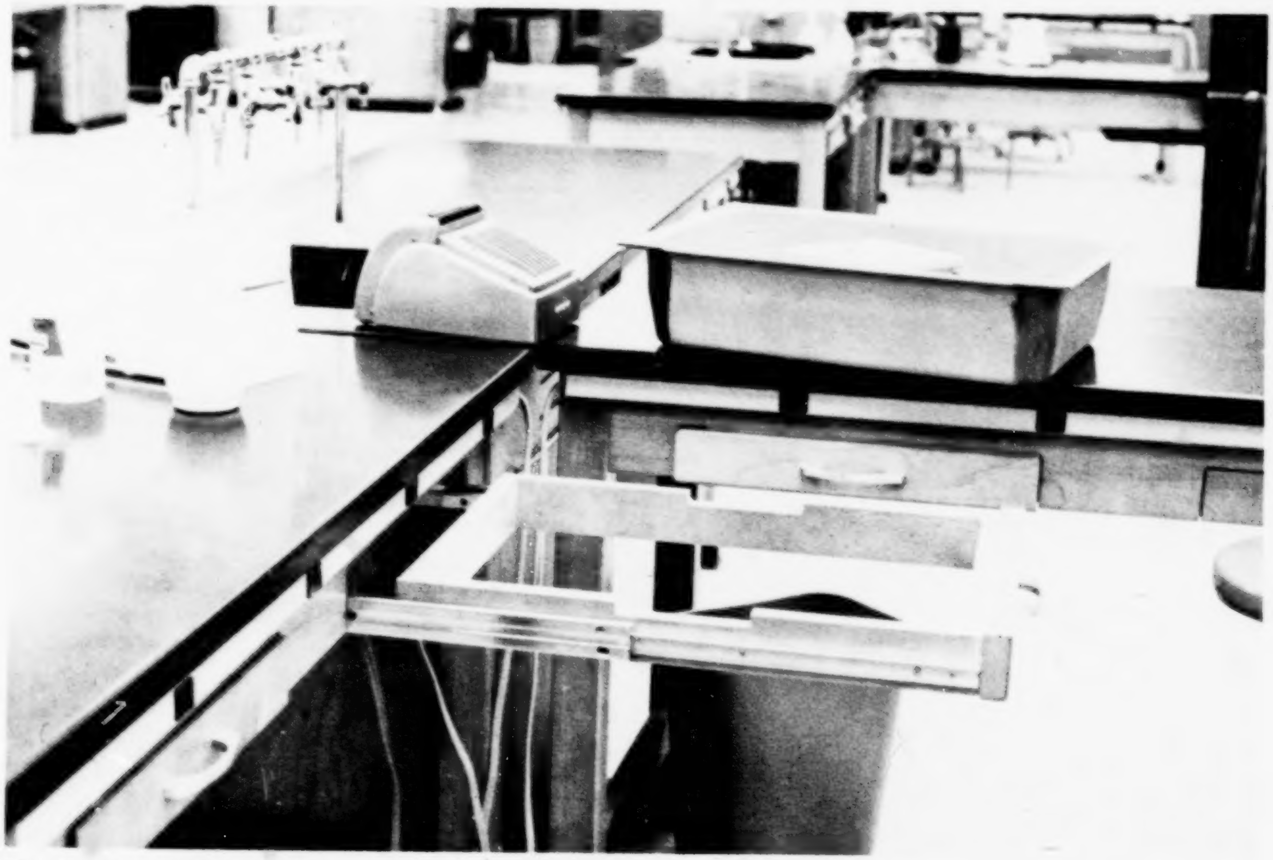
With individualized programs, storage facilities distributed around the laboratory are relatively useless. Much more appropriate are central storage facilities for all materials, including those needed by students for individual experiments. There is also a need for a different allocation of materials. While 30 microscopes may be needed for each science laboratory in a traditional pattern, 10 or 15 microscopes may suffice for 100 or more students using a given facility in individualized study programs. When students are moving on individual schedules and are using materials at different times, it is usually possible to have fewer items of any given piece of equipment, and thereby allow for the purchase of a much wider variety of equipment and supplies. Individualized programs require many kinds of materials and equipment.

There are some conspicuous advantages in central storage of materials and equipment. Storage shelves can be simple and relatively inexpensive. Cabinets mounted on walls and laboratory furniture with cabinetry built in are expensive. With central storage of materials, homemade shelving or other forms of shelving can provide space for storage of materials from one-third to one-tenth the cost of storage cabinets located in science laboratories.

It is highly desirable to have some kind of technical assistance in situations in which central storage facilities are used. In some schools, technical assistance is provided by student aides, sometimes paid modest hourly wages and sometimes recruited from volunteers who are interested in science. In some schools, a combination of paid laboratory aides and student assistants proves to be both effective for maintenance of materials and educational for those students involved in the program.

The most advanced logistic system observed in any school was at St. Andrews Presbyterian College at Laurinburg, North Carolina. Figures **5.8** to **5.14** show several scenes from this facility. This facility serves all science classes at St. Andrews College. Although this is a college facility, the study team sees the concepts employed here as applicable to secondary schools as well. Smaller schools would employ a less elaborate record-keeping system and a smaller technical staff.

Figure **5.8** shows a work station in the St. Andrews laboratory facility. A tote tray and sliding drawer that holds the tray can be seen in this view. Also shown is an intercom unit which allows the student to communicate with the stockroom and place orders for materials needed. Figure **5.9** shows the general aspect of this laboratory. Tables are arranged around service islands. These service islands are removable, and all utilities connect by plug-in units. Thus the laboratory can be arranged to accommodate almost any kind of science program. All of the science courses at St. Andrews are offered through this facility.



5.8 Laboratory tables have drawers to receive tote trays which contain the materials needed by individual students for their work. The intercom unit shown is used to order materials necessary for each experiment. St. Andrews Presbyterian College.

Supply Logistics

When the student places his order, it is received by a technician at a switchboard shown in Figure **5.10**. This ordering system works as follows:

- The student orders a set of equipment to do a certain laboratory.

- The logistics manager takes his order and assigns him a number which corresponds to a certain tote tray space. Figure **5.11** shows an area of the wall used for tote trays.

- Until the equipment is ready, the tote tray in that space is turned so that its red end is toward the students' side of the wall.

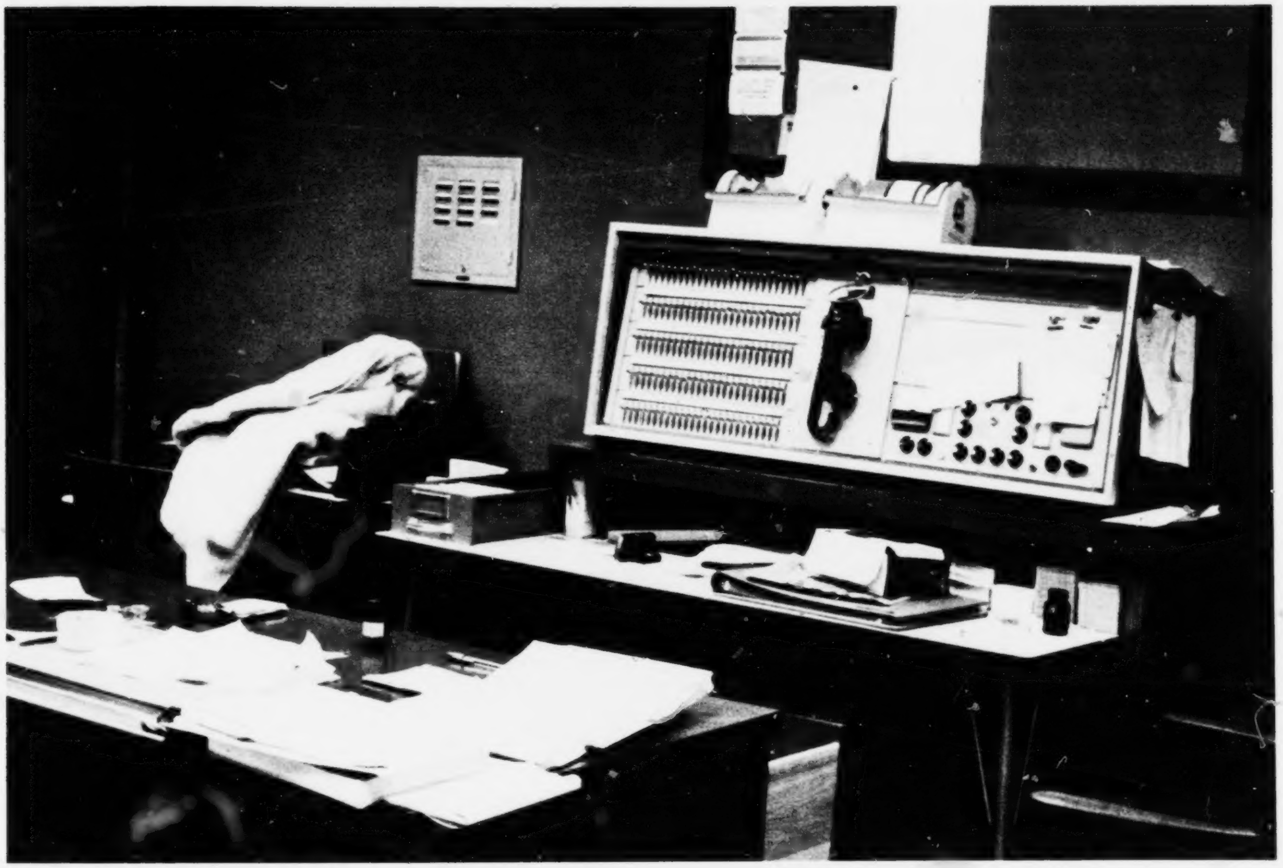
- When a student assistant fills the order, he puts the materials in a tote tray and turns the tray around so that the green end of the tray is on the students' side of the wall.

- When the student who places the order sees the green end of the tray, he knows that his order has been filled.

- Some orders may take only seconds to fill, while others are placed a day earlier to be ready for the next laboratory period.

- A check-out card is filled out by the student placing the order. This card is used to check over equipment after it is returned.

5.9 The service wall of the laboratory has many cubby holes where tote trays and other supplies are distributed to students. St. Andrews Presbyterian College.

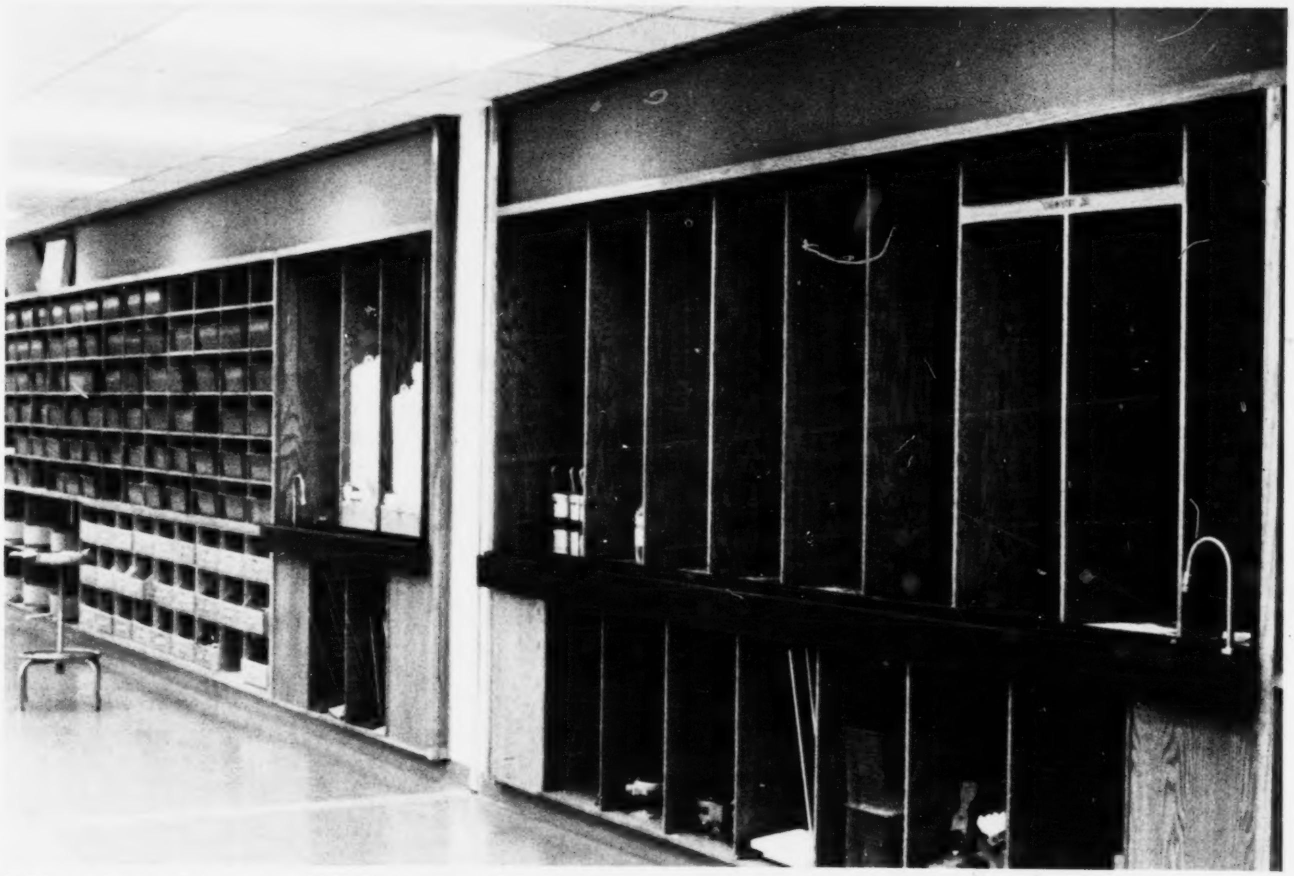


5.10 Orders for materials are received at this control panel and passed along to technicians who assemble necessary equipment and supplies. St. Andrews Presbyterian College.

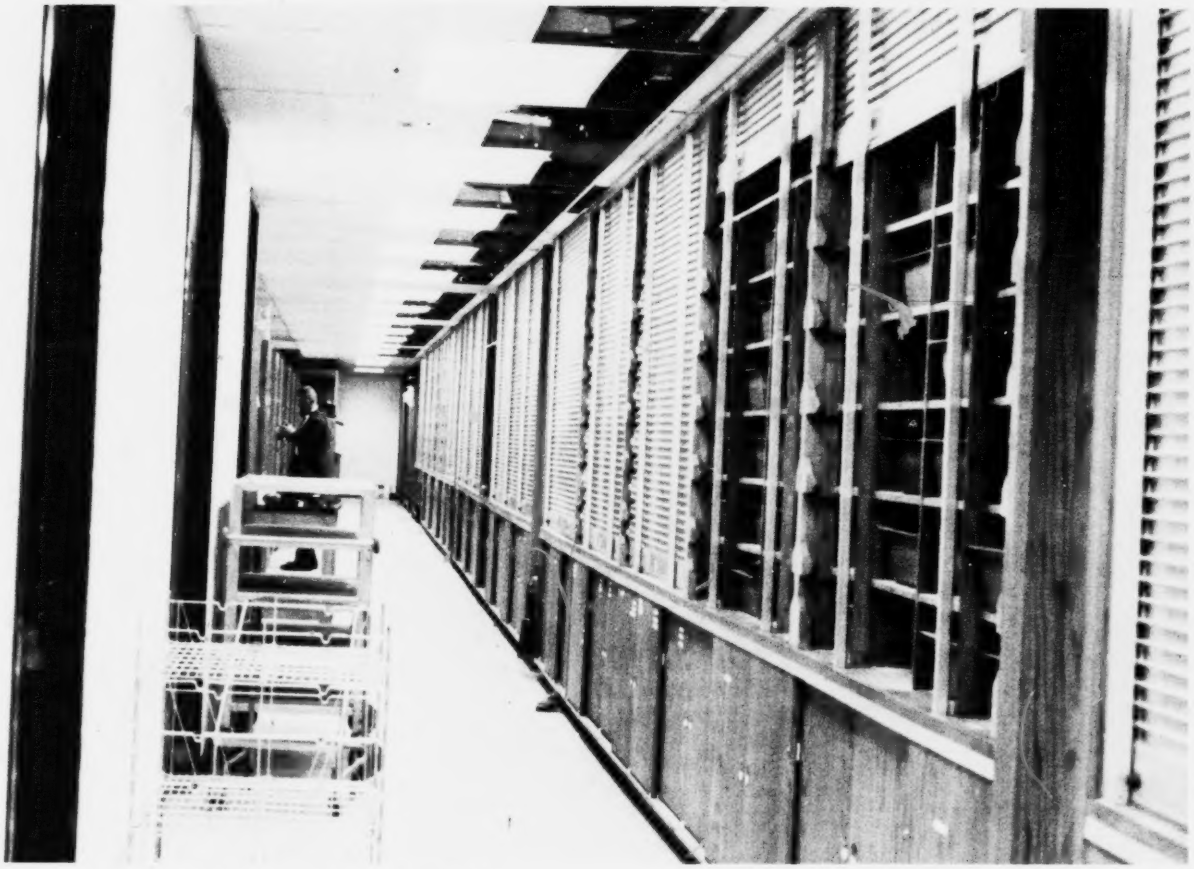
5.11 When the student's order is ready, it is placed in the cubby holes shown here. Tote trays are color coded on the side, and the green end of the tote tray signifies that it is ready for the student. St. Andrews Presbyterian College.

Supply Logistics

Larger items of equipment can be placed in the cabinets shown in Figure **5.12.** In this way, any kind of material or supply needed by a student can be provided within a matter of minutes. The materials are stored on shelves in the preparation room. Figure **5.13** shows the service area in the preparation room and sliding doors that can be lowered across the tote trays and other cabinets through which materials are passed.



5.12 Larger items of equipment can be distributed through the cabinets shown here. St. Andrews Presbyterian College.



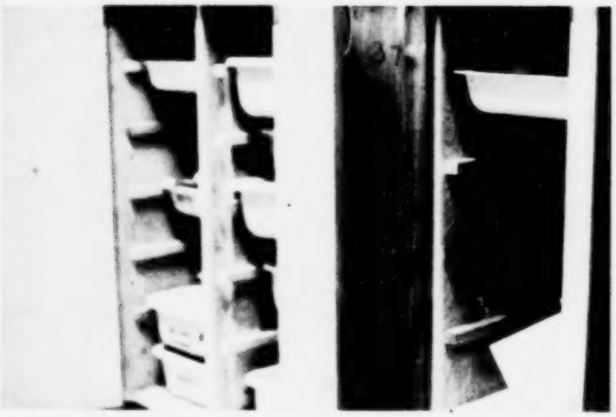
5.13 Folding doors slide up when the service wall is in use and can be lowered for security. Storage shelves are shown to the left in this view, and rolling carts are also visible. St. Andrews Presbyterian College.

Supply Logistics

Materials are maintained by technicians as shown in Figure **5.14**. Here a technician is replenishing stocks of corks and rubber stoppers. The technicians also assemble the materials requested by students. In a large logistics system such as this, a full-time stockroom manager plans for equipment and materials needed throughout the school year, based on needs anticipated by instructors.

The system at St. Andrews College allows almost unlimited flexibility in the kind of experiments that students can do on any given day. Moreover, the student does not spend time in line waiting for materials, nor does he need to shuffle through a drawer of miscellaneous apparatus to find the items to be used in a given experiment.

Less elaborate but similar logistics arrangements were seen in several secondary schools. Figure **5.15** shows a technician preparing materials for laboratories at Nova High School. In another similar facility at Nova, tote trays such as those shown in Figure **5.16** are dispensed to students.



5.16 Tote trays containing materials for different experiments are maintained in the preparation room and distributed by a technician. Nova High School.

5.14 Here a technician replenishes stocks of corks and rubber stoppers. St. Andrews Presbyterian College.

5.15 This technician prepares laboratory kits and distributes them to students when they are needed. Nova High School.

Supply Logistics

The preparation of materials for experiments and distribution to students is done by the laboratory aide. Sand Ridge Junior High School employs a laboratory technician shown behind the windows in the preparation room in Figure **5.17.** She is assisted by student aides who receive science credit for their work in the preparation area. This technician, together with aides, maintains all of the equipment and materials and dispenses them to students in this junior high school. Figure **5.18** shows a secretary who provides clerical assistance to the science department at Sand Ridge. She prepares study guides, examinations, and maintains records of all the students. With these forms of assistance, teachers are freed to work with students as they progress through their activities on an individual schedule. With the fine arrangement of logistics in technical support, students get more individual attention than they would under traditional programs. With such logistics arrangements and technical assistance, science instruction can be individualized, providing for efficient use of time by both students and staff. Figure **5.19** is another view of the science area in the Sand Ridge Junior High School.

5.17 The stockroom shown behind the windows is managed by a full-time technician who, with student assistants prepares laboratory kits and distributes them to students as they are needed. Sand Ridge Junior High School.

5.19 With instructional materials providing much of the guidance needed for individual study, and with technical support, the teacher is free to work with individual students or small groups of students. Here the science teacher is describing the program to the project director. Sand Ridge Junior High School.

5.18 This secretary maintains test records, progress charts, and assists the science staff of this junior high school with all forms of clerical aid. Sand Ridge Junior High School.

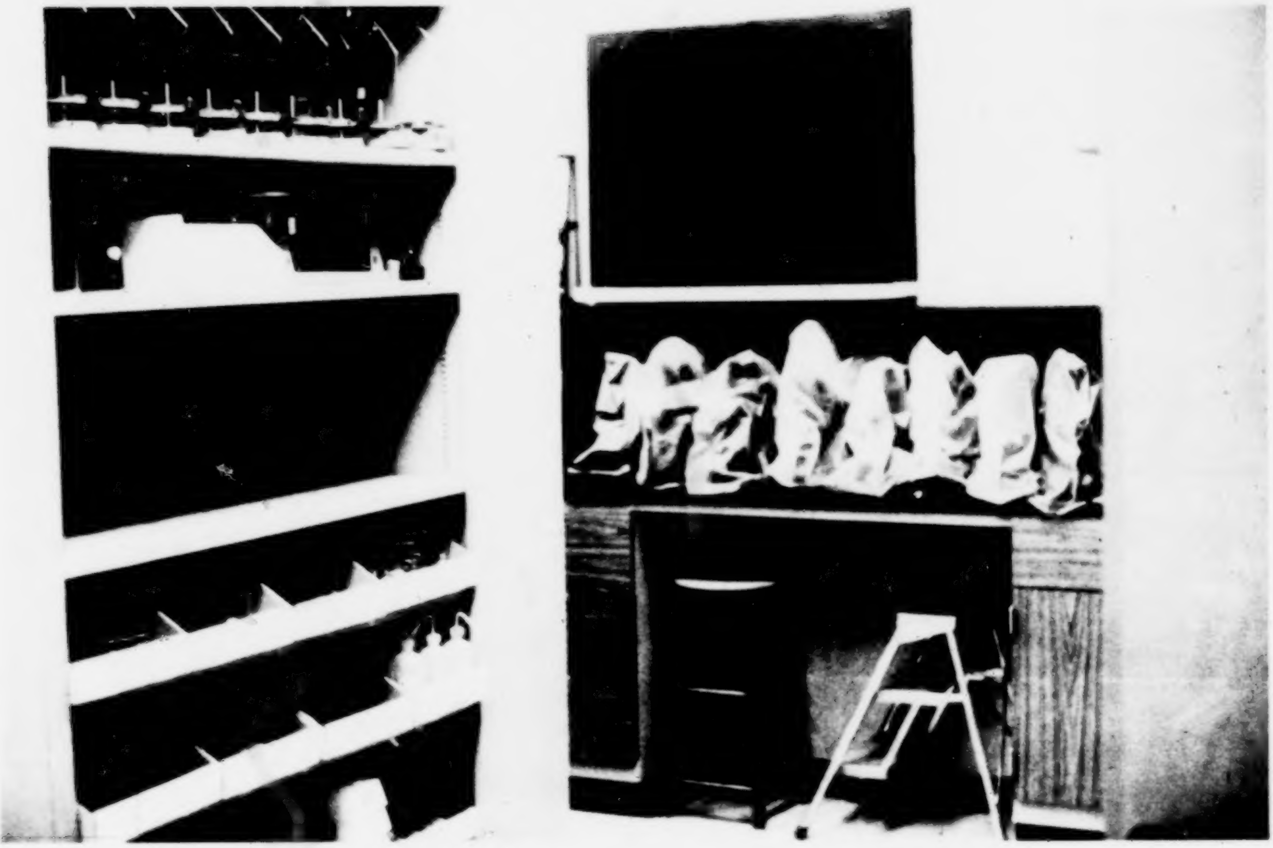
Supply Logistics

At another school, a central facility is also maintained by a technical aide who also serves as a custodian. A technical facility is shown in Figure **5.20.** However, arrangements for distribution of material to students does not include a system of tote trays or other convenient mechanisms.

5.20 This preparation area is maintained by a custodian who works part-time in support of the science program. Maine Township High School North.

In traditional science facilities, materials are frequently stored in cabinets, such as those shown in Figure **5.21.** The microscopes in these cabinets are not easy for students to remove, and the cabinet space is used very inefficiently. In contrast, central storage of microscopes shown in Figure **5.22** provides inexpensive, easily accessible storage.

5.21 Wall storage of microscopes and similar equipment is very inconvenient and expensive.



5.22 Storage of microscopes on shelves allows easy access with inexpensive storage units. Oak Grove Junior High School.

Supply Logistics

Where limited space is available for central storage, cabinets on rollers such as those shown in Figure **5.23** might be considered. These cabinets are easily separated and they expose a large volume of storage space. When materials are dispensed from a central storage area, rolling cabinets such as those shown in Figure **5.24** are handy and convenient to use.

We observed the use of rolling cabinets such as those shown in Figure **5.24** in some facilities. This arrangement allows for an intermediate form of flexibility, since the cabinets can be rolled to central storage and filled with materials needed for a given set of experiments. When lab aides are available, they can maintain a reasonable variety of materials at student laboratory stations through the use of rolling cabinets. However, this arrangement does not provide as much flexibility as does central storage with materials dispensed directly to students.

Supply logistics can be a critical and limiting factor as programs move toward increasing individualization. Our conversations with science teachers indicate that one of the common problems teachers face in their attempts to move toward flexibility in programs for students is the difficulty in providing laboratory materials and supplies on unique schedules. With central storage and technical assistance, logistics systems can operate with almost unlimited flexibility in materials which can be provided to students at any given moment. Without effective logistics there is too great a tendency to diminish laboratory experimentation and demonstration and to resort to written materials and didactic presentations. Without the concrete experiences with materials, which students need to build primary concepts, science programs are limited in laboratory work and tend toward rote memorization of definitions and principles. Not only is most information acquired by rote memorization rapidly forgotten, but poor study habits are encouraged and negative attitudes toward science may develop. School people and architects must give very careful attention to logistics systems when they are planning new or remodeled facilities or when they are contemplating program change directed toward increasing individualized instruction.

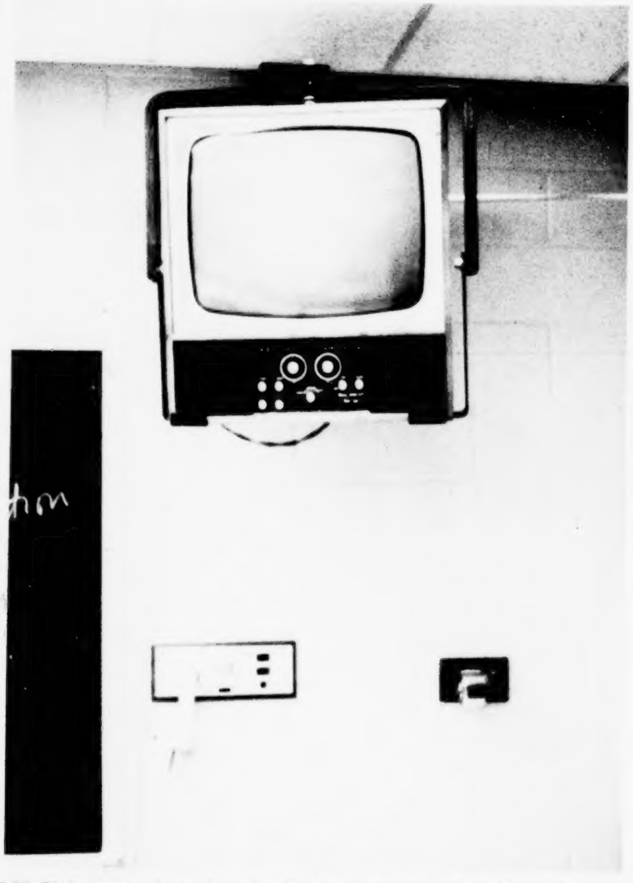
5.24 Rolling cabinets such as this are one means of distributing equipment and supplies for the stockroom to the laboratory stations. John Burroughs School.

5.23 Storage shelves on rollers provide a large volume of easily accessible storage space within a small room. Little Falls Central School.

Dial-Access & Other Technological Support Systems

Along with its promise of the use of a new technology in conjunction with educational programs, the early use of television in school instruction presented an immediate problem of providing programs to classrooms at the time they were needed. This scheduling difficulty exists even though it is possible to have a control room to distribute signals which originate from direct broadcasts received at the school or from video-tape recorders. Moreover, when a single television monitor is located in a room, all students view the same program at the same time. Television monitors, such as those shown in Figure **5.25,** were never observed in use in science classes.

The technology of dial access has been developed to reduce the problem of obtaining television programs at the time desired. In this arrangement, telephone dials activate switching equipment in the control room and video-tape decks are automatically set into operation. Depending on the code number dialed, any one of a number of programs can be available. Depending on the number of tape decks in the control facility, several different programs can be observed in classrooms simultaneously. In practice, however, it is rarely possible to have more than one program for a given subject on the tape deck. Figure **5.26** shows a bank of video-tape decks in one of the facilities visited. A technician is checking the video adjustment on the tape decks. The control room can be called by a telephone such as the one shown in Figure **5.25.** Also shown in this figure is the dial system for obtaining signals.



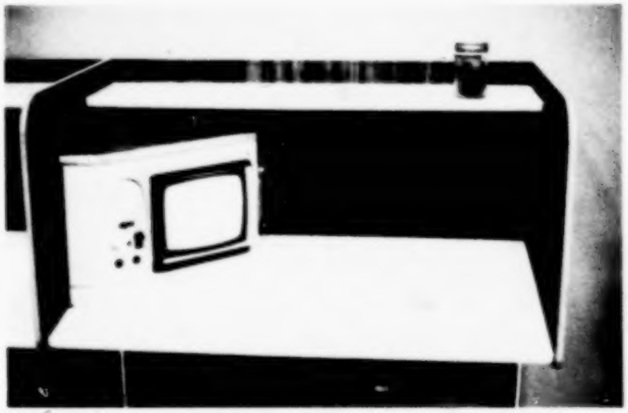
5.25 Dial-access, closed-circuit television units were never observed in use in science classes. This view shows the dialing mechanism and phone used to communicate with the control room.

5.26 Dial-access equipment requires technical maintenance as well as aids to monitor equipment. Here a technician adjusts a video tape playback unit. Coatesville Area Senior High School.

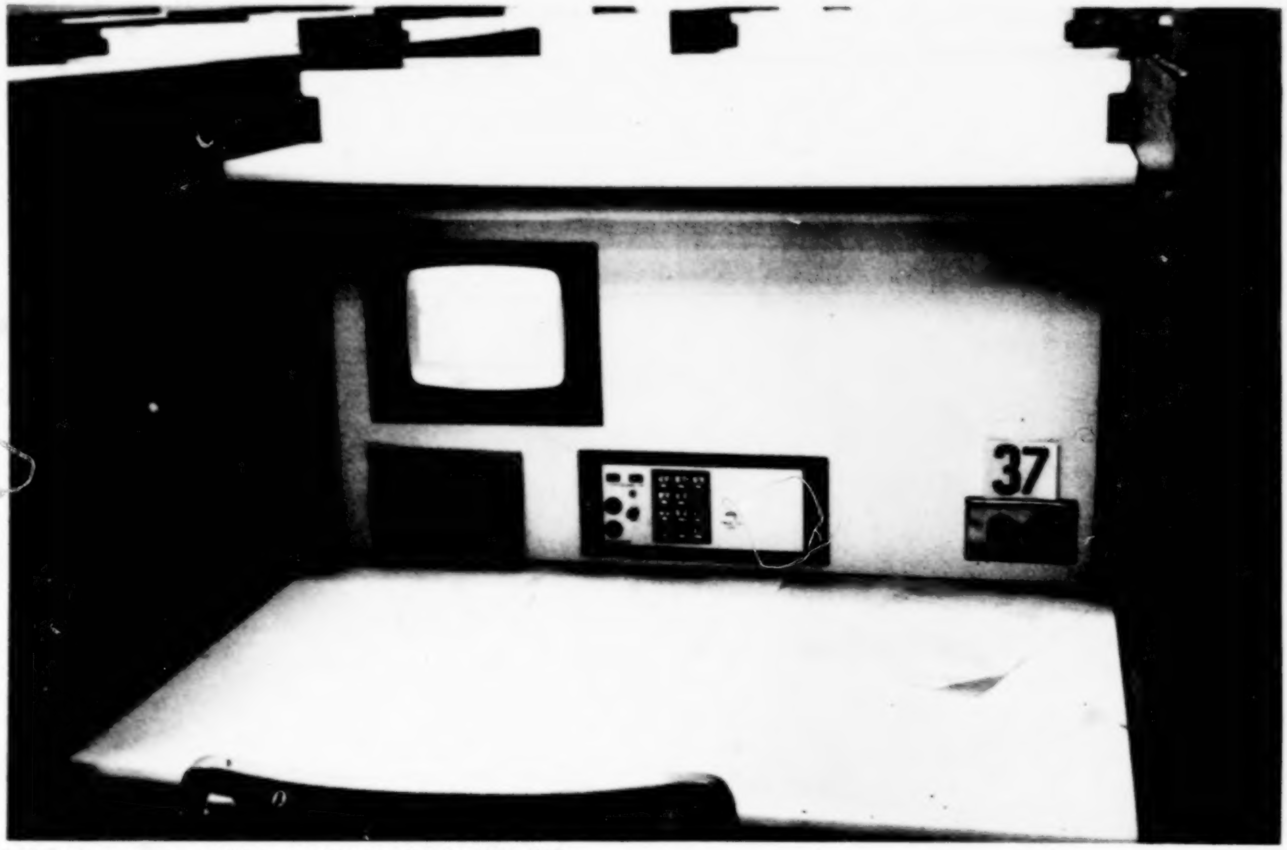
Dial-Access & Other Technological Support Systems

As the trend toward individualization increased in schools, television units located in carrels were developed for individual study. Three different kinds of dial-access carrel units are shown in Figures **5.27-5.29.** In Figure **5.29,** the conventional telephone dial is replaced by a modern touch-tone system. The switching equipment controlling signals, however, is similar.

5.28 Another type of dial-access carrel unit for video viewing or audio-tape playback. Governor Thomas Johnson High School

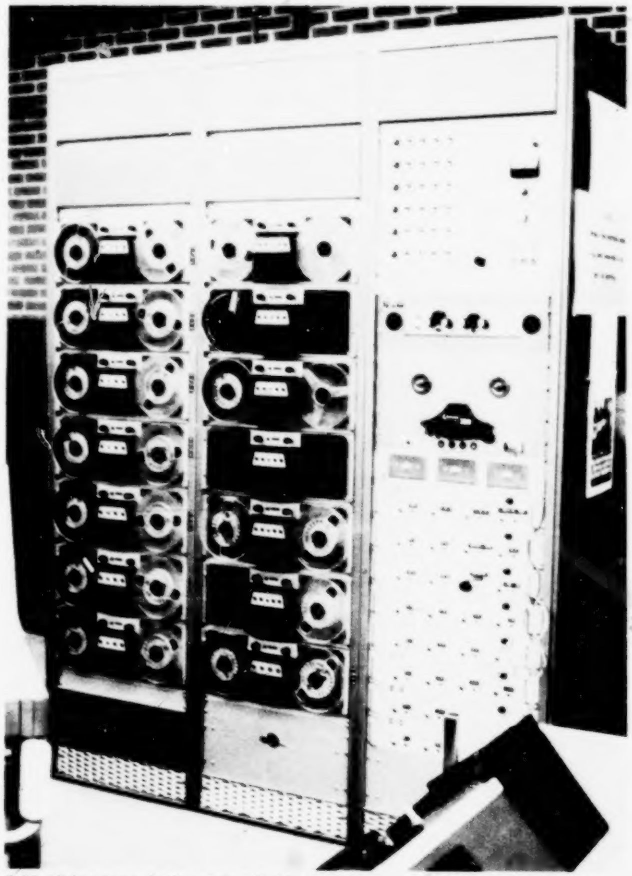


5.27 This dial-access carrell unit provides video and audio display and is large enough to be used with other learning material. Coatesville Area Senior High School.



5.29 This dial-access carrel has a touch tone system for retrieval of video or audio programs.

Dial-access instruction is available, but skilled technical support is needed. Figure **5.30** shows a technician checking a switching panel for the dial-access system. This switching equipment will activate both video- and audio-tape decks, and most dial-access carrel units do provide both. Because audio-tape decks are less expensive than video decks, more channels are usually available for audio signals than for video signals. The switching equipment and tape decks for another system are shown in Figure **5.31.**



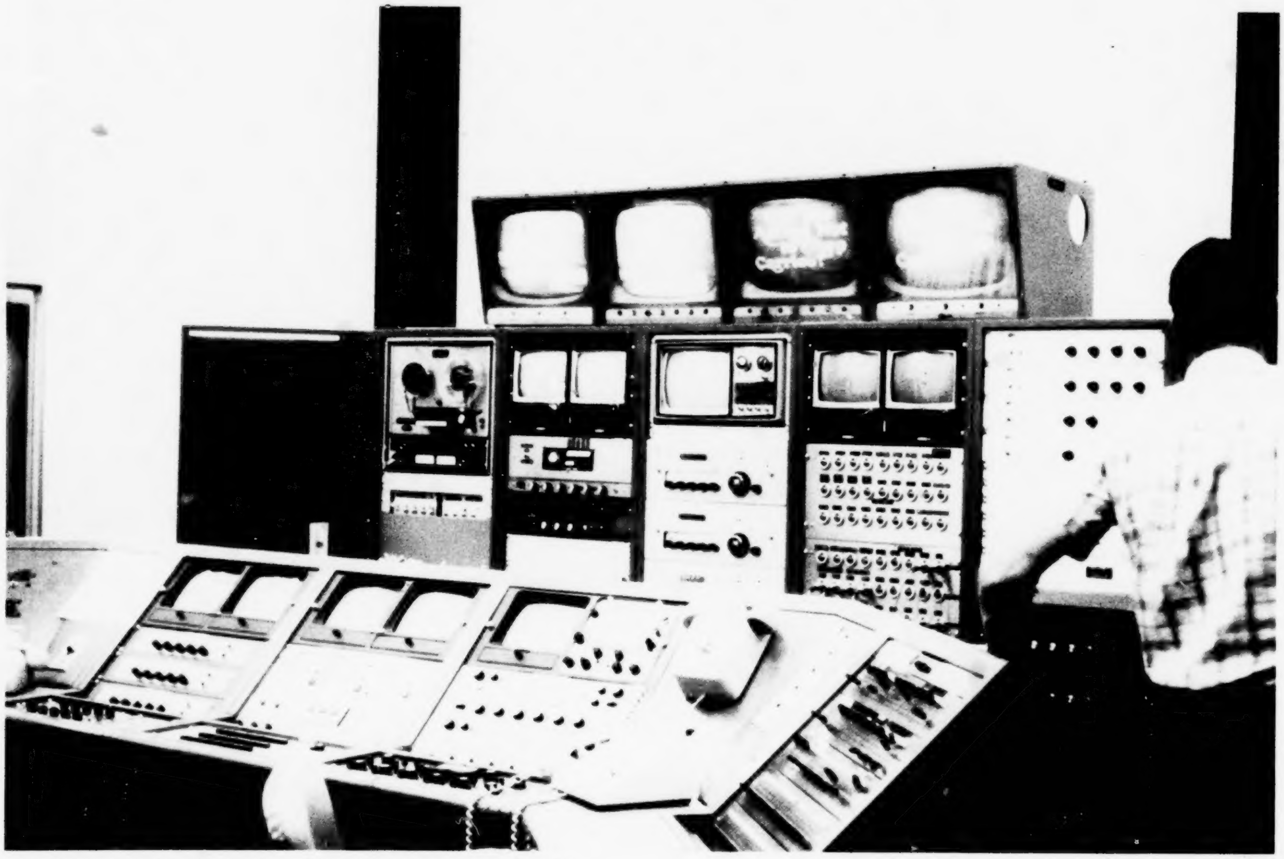
5.31 Video tape decks and switching equipment used in one dial-access system. Adams Central High School.

5.30 Dial-access equipment requires technical support staff. The technician shown here is checking a switching board for the dial-access system. Coatesville Area Senior High School.

Dial-Access & Other Technological Support Systems

If dial-access television is to be useful to teachers, facilities must be available for the preparation of original video tapes. Studio facilities such as those shown in Figure **5.32** are needed. For video-taping, technical support and control facilities, such as those shown in Figure **5.33,** must be available. There is a substantial capital investment in this kind of equipment and a continuing operating cost for technical support as well as tape equipment maintenance.

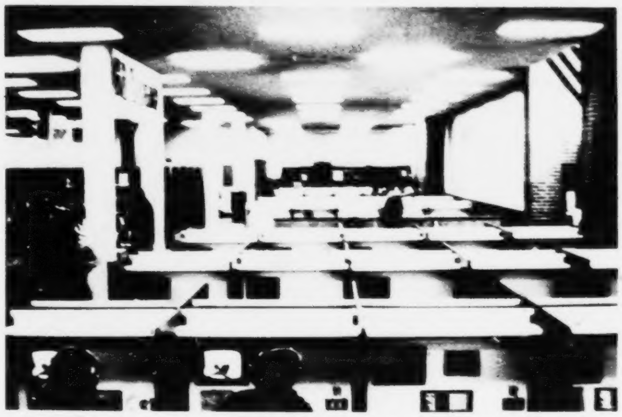
5.32 A view from the control room for a video tape studio. Shawnee Mission Northwest High School.



5.33 Video control equipment for a TV studio and dial-access system. Adams Central High School.

If carrel units are to be wired for dial-access instruction, they should be clustered for economical installation. Figure **5.34** shows a group of dial-access carrels in a learning center. Dial-access carrels may be located within a science facility, but no such arrangements were observed in any schools visited.

Present technology in dial access presents some severe limitations. When a student dials a code number to receive a video or audio signal, he receives it at the beginning of the program only when no other student is viewing the program. If another student has already dialed the lesson, any additional students will receive the program part way finished. This means that to get the entire program, students must redial it when it is completed. Students and teachers have found this to be an undesirable aspect of dial access. In Meramac Junior College, in St. Louis, dial-access audio facilities were removed from the science laboratory, even though program segments were never more than four minutes long. Students objected to the necessity of recalling programs in order to hear them from the beginning. If unlimited numbers of tape decks were available, of course, this problem could be eliminated. The costs for dial-access decks and switching equipment, however, precludes this possibility at present. Most schools have fewer than 50 video and audio decks. With enrollments of 2,000 or 3,000 students, and with the facility serving all subject areas, any appreciable use of dial access means that most students will receive programs part way into the lesson.



5.34 One section of a learning center with rows of dial-access carrel units. Shawnee Mission Northwest High School.

Another disadvantage of current dial-access technology is that there is no way that a student can back up the program to repeat a few seconds that may have been missed or that he would like to see again. Although this limitation might be overcome with more sophisticated switching and tape-deck equipment, present technology does not provide any means for reversing programs in dial access.

5.35 Portable video tape equipment that can be moved to classrooms. A student technician can assist in recording programs or playback use of the equipment in classrooms. Auburn High School.

Some schools are employing simpler video recording equipment and television monitors like those shown in Figure **5.35**. Programs can be taped on the portable tape recorder located on a shelf, and the entire cart can be rolled to the classroom where it is to be used. Relatively simple facilities will allow recording programs from commercial or educational television broadcasts, but usually studio facilities are desirable. That is to say, this kind of arrangement does not provide the convenient access to television that is available through closed-circuit or dial-access systems. Except for special purposes, video recording and viewing equipment, such as that in Figure 5.35, has little value in science teaching. The question of what investment is appropriate in dial-access or video equipment cannot be answered simply. An elaborate dial-access video system will have an initial capital cost upwards of $500,000. For a school with an enrollment of 2,000 or 3,000 students and amortizing the capital costs over 10 years, this investment in a learning aid can be available at about $20 per student per year, excluding cost for technical support. As noted earlier, this would represent about 2 percent of the total cost per child per year and might be considered if the medium is highly effective in instruction. In our view, however, present technical limitations are such that investment in dial-access or similar instructional systems must be seriously questioned.

An alternative to dial-access equipment is simple equipment available immediately within a carrel unit for individual study use. A series of carrels wired for audio use is shown in Figure **5.36**. The carrel unit contains electric outlets that can be used with loop film projectors, slide viewers, or other equipment. A reel-to-reel tape deck at the rear of the panel allows for audio-tape listening under direct control by the student. These tape decks permit the student to move fast forward or to reverse a tape at any time he desires. Thus the student has much more control over how he or she will proceed through an audio lesson. Used in conjunction with slide viewers or loop film projectors, carrels equipped with audio-tape recorders are an expensive form of technologically mediated individualized instruction. Figure **5.37** shows a carrel unit equipped for the study of taxidermy. The students are guided through observations and manipulation of materials by instruction on the audio tape, as well as through study guides and drawings. Colored slides and loop films can be observed when necessary, the latter when motion is needed in the instruction.

5.36 Carrel units equipped with audio-tape decks used for science instruction. Adams Central High School.

The cassette recorder shown in the lower left of Figure **5.37** is highly portable and inexpensive. Quality control in manufacture is not high nor are these machines designed for continuous use. About one in ten will fail within a few hours and about half will fail in a year or two of class use.

However, at $20 to $35 each, replacement of 30 percent of the machines each year is inexpensive compared to the amortized cost of sophisticated equipment. The problem is that teachers and administrators expect all equipment to last indefinitely. Flexibility includes being able to discard outmoded equipment without incurring prohibitive expense.

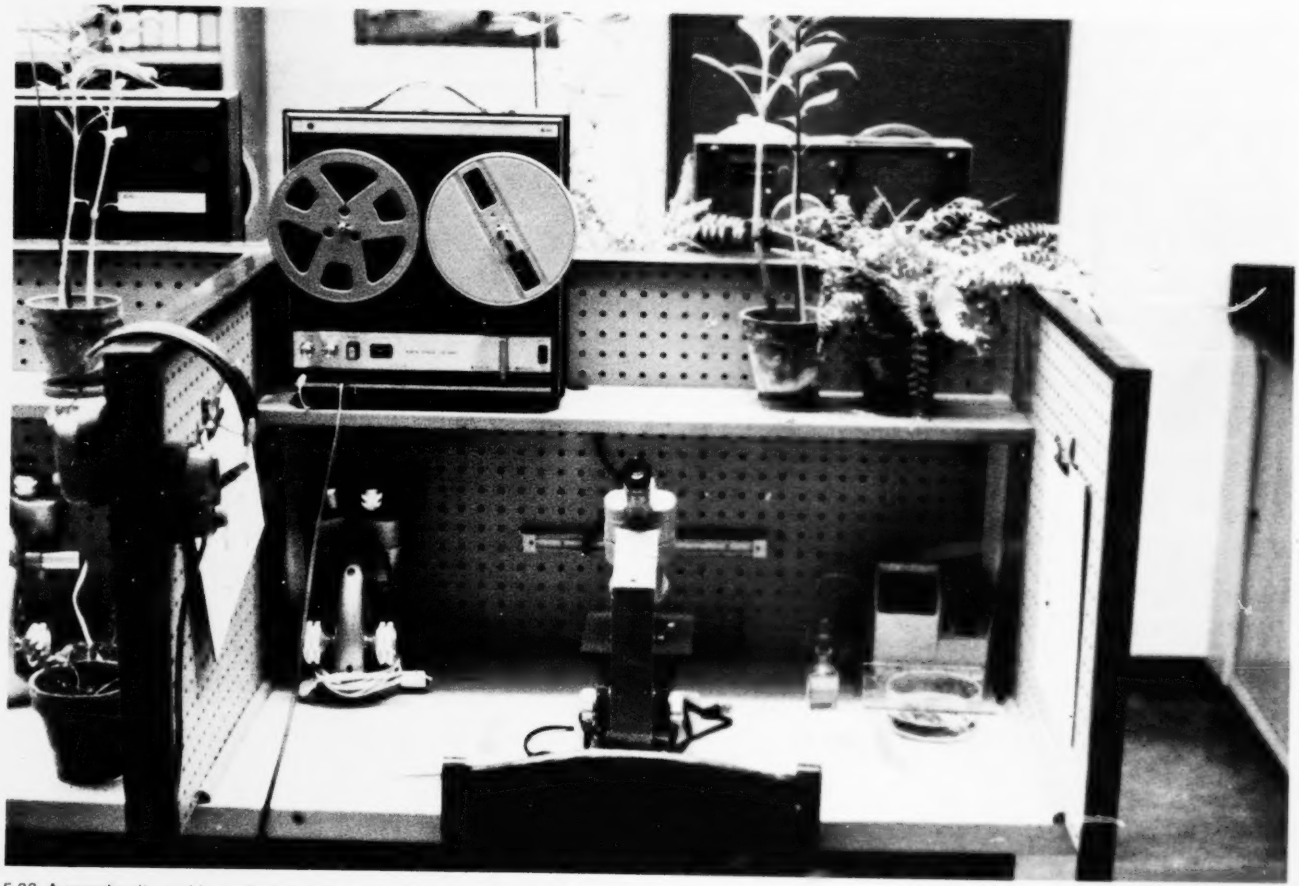
The use of another arrangement of simple audio equipment to guide students through instruction was first tested in many college science programs some 10 years ago and is commonly known as audio-tutorial instruction. (For a description of this kind of instruction see Postlethwait et al., [37] The technique is now beginning to appear in secondary schools.

How to Prepare
Small Mammal
Skins
QUAKER
YELLOW
CORN MEAL
Red Cross Cotton

5.37 A carrel unit with portable tape recorder, loop film projector, and slide viewer used in the study of taxidermy.

Dial-Access & Other Technological Support Systems

Figure **5.38** shows an attractive facility developed by a biology teacher for audio-tutorial instruction at the secondary school level. Reel-to-reel tape recorders shown had no mechanical failures in more than two years. At another school, Figure **5.39,** a student is doing an experiment in microbiology with audio-tutorial guidance. Figure **5.40** shows the carrel arrangements for still another high school biology program. These carrels were made by the teacher and are attached to old tables. A variety of learning resources are available in this room.



5.38 A carrel unit used in audio-tutorial study in biology. Equipment and materials shown here are for a lesson in botany. John Burroughs School.

5.39 A student performing an audio-tutorial lesson in botany. Charles A. Lindberg Senior High School.

5.40 An audio-tutorial carrel unit used for biology instruction. Fort Benton High School.

Dial-Access & Other Technological Support Systems

With audio-tutorial instruction, each student can proceed through lessons largely at his own rate. Since tapes are easily removed or replaced on the tape deck, students can set up their own programs and proceed on an individualized study schedule. This is especially true when cassette tape recorders are being used.

High quality, durable tape decks can be obtained for less than $200. On the other hand, portable cassette machines can be purchased for as little as $10. Although the latter machines may have a shorter life span, their low initial cost permits teachers to begin work with audio-tutorial methods at a minimum investment. There is sometimes a problem in that the tape recorders are so portable that they occasionally disappear. Some teachers issue the tape recorders along with other study materials in audio-tutorial kits. The student is then responsible for return of all materials in the kit, including the tape recorder and cassettes.

For some audio-tape equipment, controls are located in a student study station, but the tapes and electronic equipment are in a remote cabinet. Figure **5.41** shows such a bank of recorders used in junior college. This kind of equipment is highly reliable and costs less than $400 per student station, including installation. Each student station has a separate deck, and the student can start, stop, or reverse the tape at will. This college had used dial-access audio equipment but removed it as a result of the dissatisfaction of students and staff.

As more schools move to simple, individualized technological support of science instruction, we are likely to see more and more student participation in the preparation of lesson materials. Many students are interested in photography and electronic equipment, so there is a natural inclination toward working with these teaching aids. Where teachers provide some guidance, both in the use of media and in subject matter to be presented, students have been highly successful in preparing audio-tutorial lessons. [38]

5.41 A bank of recorders located in a remote cabinet.

5.42 Calculators in a study room used by science and mathematics students. Greenwich Senior High School.

It is too early to predict how widespread this kind of technological support will become in science programs, but at present, there appears to be more promise for audio-tutorial technical support of instruction than for the vastly more expensive dial-access or video-tape systems. Our own enthusiasm for audio-tutorial methods derives in part from the opportunities presented for teachers and students to work together in creating learning materials, as well as in the process of instruction *per se*.

Computer facilities are a necessity for modern science programs. At present, mathematics teachers are more likely to request computer facilities and provide instruction in their use than are science teachers. However, many science students use the computer training obtained in mathematics to solve science problems. We recommend that computer facilities be planned as part of the science area, or computers should be available in close proximity to science facilities.

Computer-assisted instruction in secondary sciences has not developed to a significant level, partly due to development costs, partly due to the active laboratory phase of viable science learning. However, one promising development is the collecting of data into a simulation experience as a means of extending student involvement with data and equipment not locally available.

Various types of mechanical calculators, such as those shown in Figure **5.42** have also been used in schools. The facilities shown in this figure and in Figures **5.43-5.46** all are facilities shared with math departments. Small electronic computers are rapidly replacing mechanical calculating machines. Several stations such as the one shown in Figure **5.43** can be connected to a single master unit. IBM punch cards and more sophisticated equipment are also being used. Figure **5.44** shows students working with computer facilities using data cards. In Figures **5.45** and **5.46** other computer facilities are shown. Computer technology is advancing rapidly. New kinds of equipment and new lease or purchase programs will be offered. In all probability, greater use of remote computer facilities and remote information sources will increase. Telephone circuits with various kinds of data-processing equipment attached are already important in many commercial uses. Planning of science facilities should include stations for telephone hookups for data-processing equipment. As student activities draw increasingly on community resources, telephones for student use in planning and executing study projects will become a necessity.

5.43 A small electronic calculator used in a junior high school science program. Four similar keyboards can be attached to a single master unit, located below the desk. South Glens Falls Central School

5.44 This electronic data processing equipment is used by students in science and mathematics. Mariemont High School.

5.45 Key punch machines and a computer terminal (rear) are shown in this view. Munster High School.

5.46 Science and mathematics students share in the use of these computer facilities.

Special Resources

The study team visited a number of natural areas, both those on school grounds and those located in special areas away from the school. Frequently these are community resources available to adults as well as to school children.

One kind of high school facility frequently used by the community and elementary school classes is the planetarium. Figure **5.47** shows the projector in one facility with students examining a projection slide. Most schools that have planetaria and adequately trained faculty find this to be a worthwhile special resource.

Parks, museums, special exhibits, and other public facilities can be valuable resources for science programs. Due to the variety and local nature of these facilities, this report will not describe features for integrating these learning resources into school science programs. However, the annotated bibliography includes published reports that show ways in which these facilities have been used to support science programs. We urge teachers to study recent publications as well as their own local resources to discern how facilities outside the school building can become a part of the science teaching resources of the school.

5.47 The students shown here are viewing a slide for a planetarium projector. This facility is used by all of the students in the high school as well as community groups. Little Falls Central School.

Chapter 6

Conclusions

The initial objectives of this study were to identify some of the most outstanding science facilities in the country and to determine what characteristics of these facilities made them exemplary. Our study team, all experienced in secondary school science teaching and supervision, solicited nominations from a variety of sources and selected schools for site visitation. Collectively the team visited 140 secondary schools and supporting science facilities. We consulted with architects and sought counsel from a distinguished board of consultants. This report was based on the information we received through our visits and consultations. It represents a composite of observations more extensive than heretofore available in any study of science facilities.

Early in the study we directed most of our attention to facilities and their potentials as well as their limitations for augmenting flexibility in science programs. As our study progressed, it became increasingly evident that we could not isolate considerations of the science program and relations between students and staff members from the physical characteristics of science facilities. We gathered information on all of these dimensions, and we have attempted to assemble a coherent statement that may be directive in modifying current programs and facilities or in planning for new facilities.

Through our conversations with staff members and students, we identified a number of concerns relative to the appropriateness of various kinds of facilities and also to recent or planned changes in science programs.

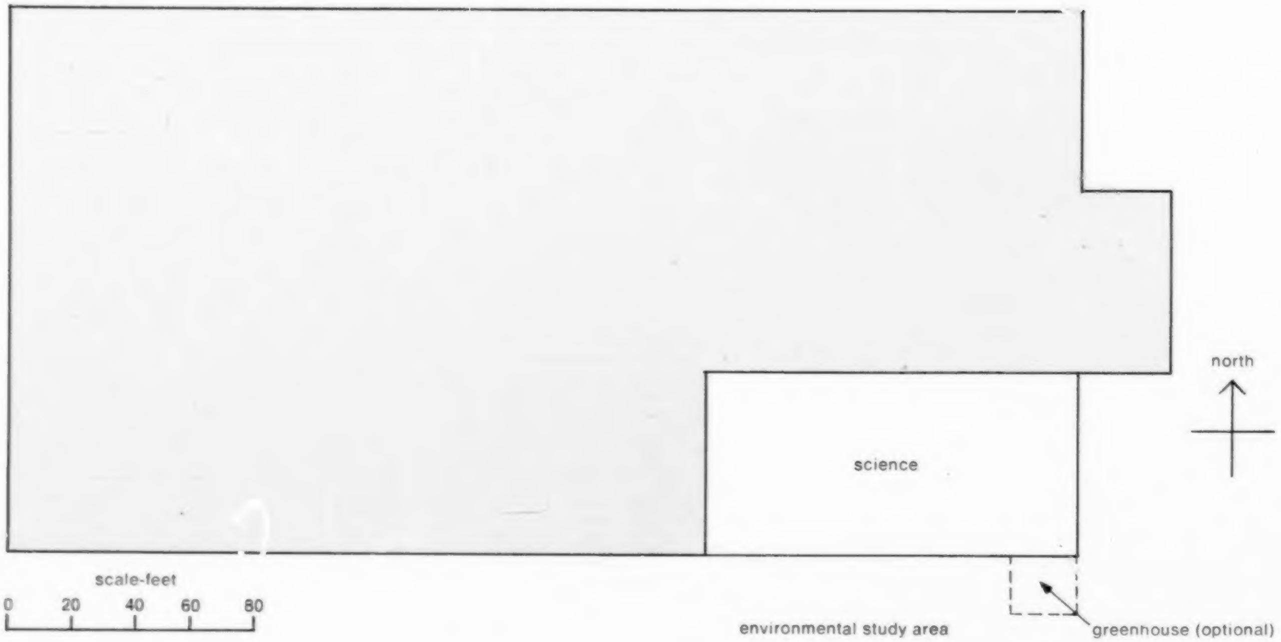
These conversations showed many common concerns and attempts at solutions to problems. From the evidence obtained, the study team developed four *evolving patterns*. These patterns and their implication for school planning were described in Part 1 of this report. The patterns show changes in programs and facilities that are evolutionary in character. In this chapter we present some suggestions for the design of facilities which would represent the best composite we can make on the basis of our observations and interpretations. The following seven categories will be used to summarize our findings:

1. Location of science facilities
2. Alternative arrangement of facilities
3. Laboratory furnishings
4. Supply logistics
5. Technological support
6. Human environment
7. Community resource utilization

Conclusions

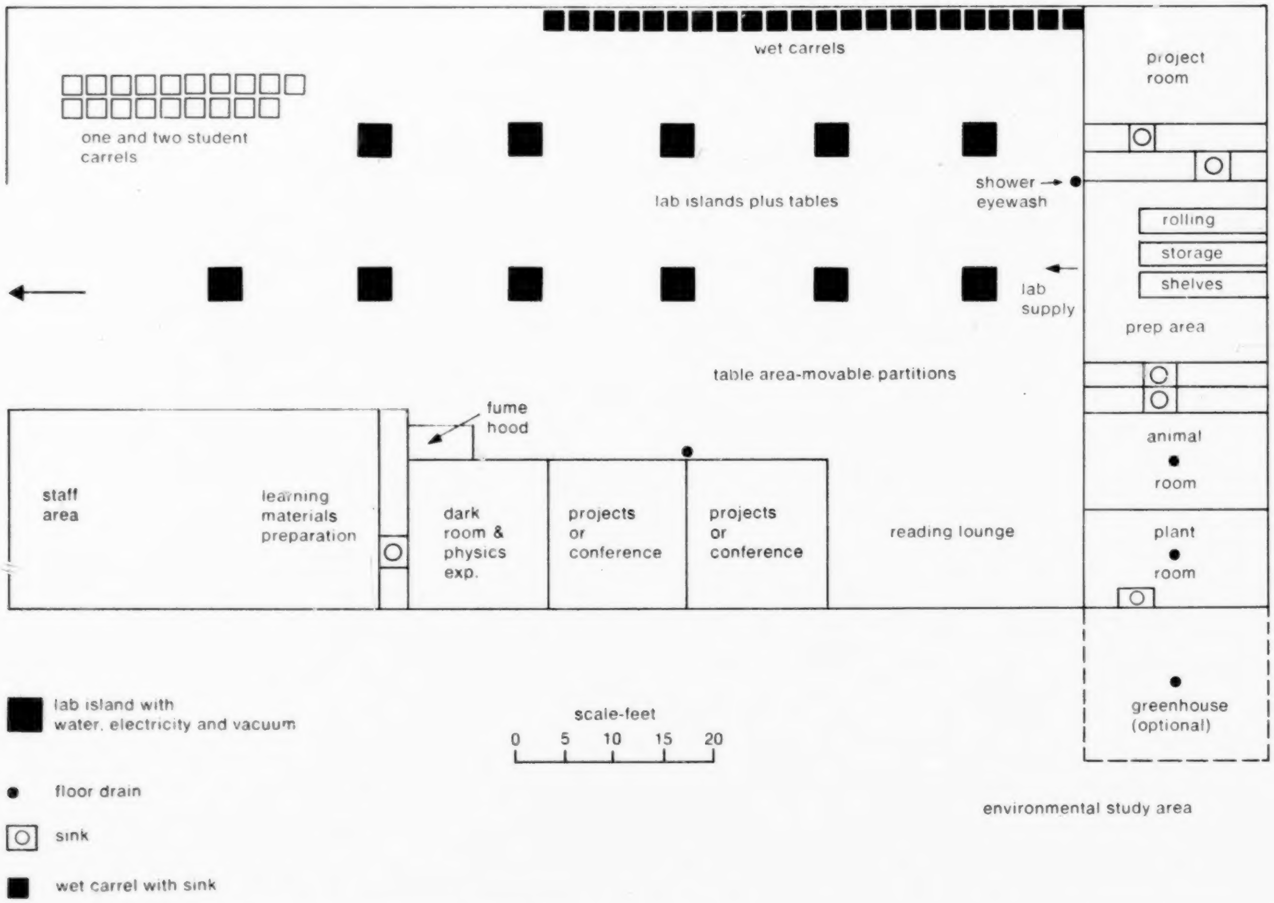
1. Location of Science Facilities

We recommend that science areas be located as close as possible to areas for other disciplines that are inquiry oriented. For example, concerns for environmental quality may be as much a part of the social sciences as of the sciences. Proximity of science areas to the social science areas can allow for cooperative program development between these disciplines. There is a trend toward interdisciplinary programs, and the physical location of facilities may contribute to integrated study and individualized program development.


north
science
scale-feet
0
20
40
60
80
environmental study area
greenhouse (optional)

6.1 A general layout for a secondary school enrolling approximately 500 students.

Figure **6.1** shows a general layout for a secondary school of approximately 500 student enrollment. Figure **6.3** shows a suggested arrangement for a larger school, enrolling 1,200 to 1,500 students. The importance of mathematics to science is widely recognized, and it continues to be useful for the two departments to share resources, especially computer facilities. The science facilities should be conveniently located with respect to the general learning center of the school.


wet carrels
project room
one and two student carrels
lab islands plus tables
shower eyewash
rolling
storage
shelves
lab supply
prep area
table area-movable partitions
fume hood
animal room
staff area
learning materials preparation
dark room & physics exp.
projects or conference
projects or conference
reading lounge
plant room
greenhouse (optional)
environmental study area
lab island with water, electricity and vacuum
scale-feet
0
5
10
15
20
floor drain
sink
wet carrel with sink

6.2 The science facility for a school with enrollment for 500 students.

Conclusions

2. Alternative Arrangements of Facilities

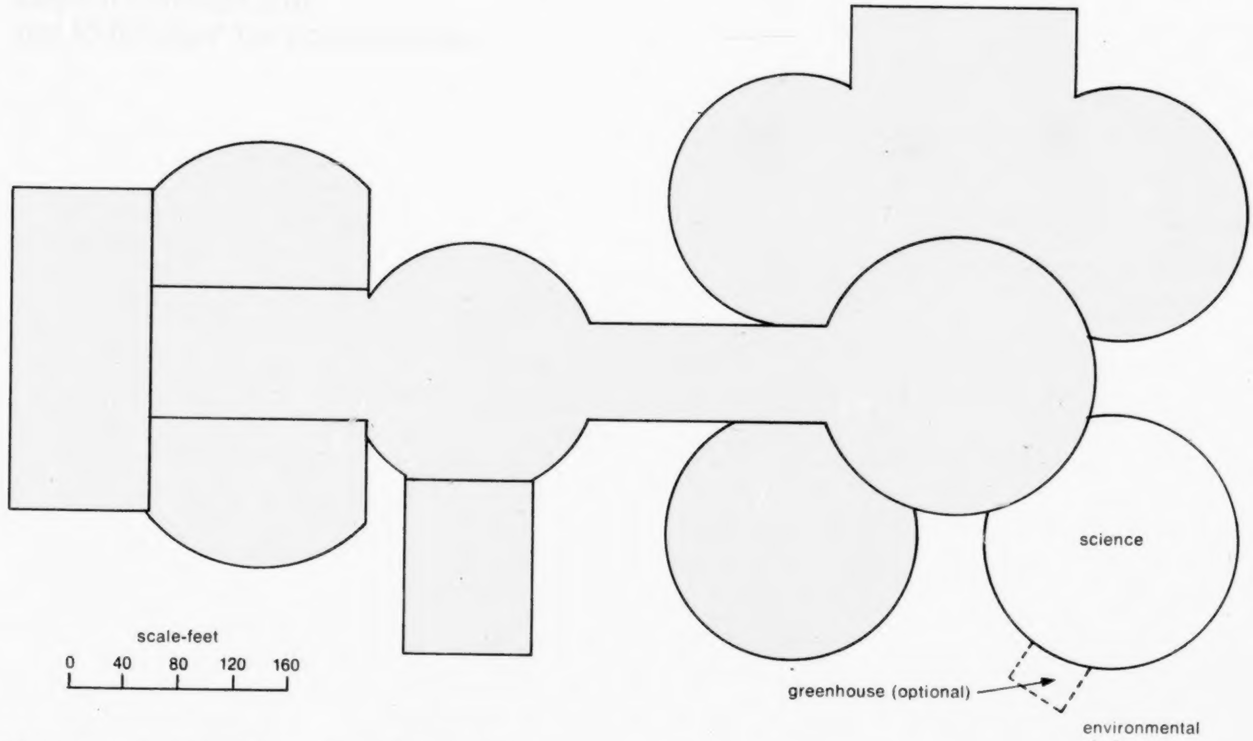
An unlimited number of space configurations are possible when new construction is planned. Figures **6.2** and **6.4** show two arrangements of a science area that might be considered when new construction is planned. The amount of space allocated to science varies from school to school. Most schools have the equivalent of 10 square feet of science area per student enrolled in the school. However, science areas vary from as little as 4 square feet to more than 40 square feet per student enrolled in some private academies. The floor plans shown in Figures **6.2** and **6.4** provide about 15 square feet per student, an allocation we believe is reasonable, especially in view of the flexibility available to allow various future uses of this space. Detailed specifications for the design and equipment of these facilities were described in Chapters 4 and 5.

3. Laboratory Furnishings

Our present "ideal" facilities for the science area would include the following. Substantial numbers of trapezoidal tables that can be arranged in various configurations for individual study, small-conference activity, and lecture-discussion. Where water, electricity, and drains are required, we recommend laboratory islands and light, adjustable tables, as shown in Figure **6.5.** Where building codes permit, or authorities can be persuaded to accept the arrangement, laboratory islands should be of a type that can be unplugged and moved to alternate locations. Sufficient mechanical supply "wells" should be planned into the floor area to allow for present needs as well as possible alternative future needs. For economy, the laboratory islands can be located in selected areas of the science facility, as shown in Figures **6.2** and **6.4.**

For some experimentation, peripheral laboratory benches with gas, water, and electricity provide useful work areas, especially for those experiments where gas is needed.

Rolling cabinets of various kinds should be available. Also, combination chalkboard, tackboard, and space dividers should be on rollers and available in adequate quantities.



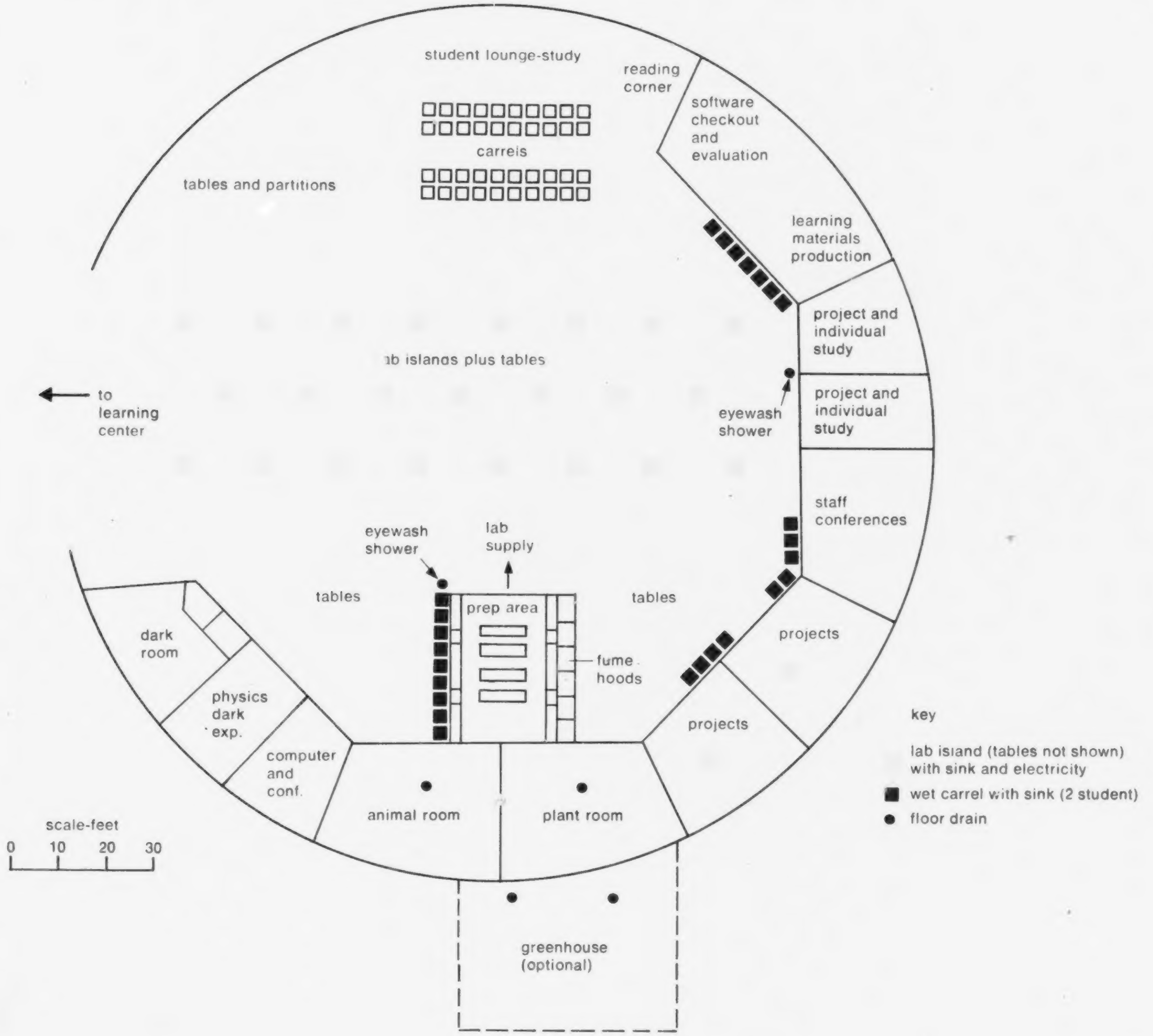
6.3 A general plan for a secondary school enrolling 1200 to 1500 students.

4. Supply Logistics

A preparation-storage-distribution area should be large enough to accommodate all the activities occurring there. One good arrangement is shown in Figure **6.4.** For smaller or larger schools, the facility can be correspondingly modified. The facility illustrated would be adequate for schools enrolling approximately 1,400 students. Separate areas for distribution of software and for student evaluation are shown. The total area is supervised by an aide who also assists in record-keeping. Both students and staff use part of this area for production of learning materials including audio-visual aids. Additional technical help might also be provided here.

5. Technological Support

Our recommendations for technological support include portable, inexpensive carrel units equipped with electric outlets and with adequate audiovisual equipment available through the supply center. Some carrels should include the possibility of more sophisticated experimentation. We are recommending that carrels be designed so that they can be used by two students, although some single student carrels are also included in Figures **6.2** and **6.4.**


student lounge-study
reading corner
software checkout and evaluation
carrels
tables and partitions
learning materials production
project and individual study
project and individual study
lab islands plus tables
to learning center
eyewash shower
staff conferences
eyewash shower
lab supply
tables
prep area
tables
fume hoods
projects
projects
dark room
physics dark exp.
computer and conf.
animal room
plant room
greenhouse (optional)
scale-feet
0
10
20
30
key
lab island (tables not shown) with sink and electricity
■ wet carrel with sink (2 student)
● floor drain

6.4 A plan for a science facility for a school of 1200 to 1500 enrollment.

Conclusions

6. Human Environment

The entire science area should be carpeted. This and other acoustical treatment will eliminate most undesired noises at their source. With carpeting, any corner can become an excellent study area, and hallways, too, can be used for study as shown in Figures **6.6** and **6.7.** The heating, ventilation, and air-conditioning systems provide air at appropriate temperatures and with appropriate humidity levels. Control of humidity not only provides a healthy environment for students and staff but also reduces problems associated with maintaining living organisms within the laboratory facilities. There are many areas for isolated, quiet study, as well as open areas for various kinds of group involvement. Facilities for groups of 6 to 12 students are available throughout the area, with movable walls, cases, and tables forming the areas as desired. Areas of this size are frequently ideal for active exchange of ideas by students and / or staff. Some groups could also meet in project or conference rooms.

7. Community Resource Utilization

Although they cannot be shown on plans for school buildings community resources available to augment science programs must be considered. Surveys should be made of public and private facilities that are convenient to the school and available for use by the students. Facilities and other resources may change from year to year, and an annual survey should be planned by staff and students. When the survey is completed, cooperative student-staff planning of possible ways in which these resources can be used should also be a part of the regular program.

6.5 A laboratory island with movable tables provides maximum flexibility in laboratory facilities. Wherever building codes permit, the island units should be of the plug-in, portable variety. Oak Grove Junior High School.

The physical arrangements shown in Figures **6.1** to **6.4** are not intended to be working plans for an architect. Any good architect must draw on his own interpretation of the needs perceived by his clients. Our purpose in presenting these plans is more as a source of information for the discussion of plausible alternatives, not as a "blueprint" to be followed. We have purposely limited the number of floor plans in this book to emphasize that primary attention must be directed at analysis of the *purposes* a facility is to fulfill. Too often school planning committees become preoccupied with the details of blueprints and construction, with no one directing primary attention to the present and future educational programs to be served by the building. Often those that do are listened to but not heard.

When local building committees are established, careful attention should be given to inclusion of one member who knows architecture and can act impartially as an interpreter between the committee and the architectural firm. Obviously this liaison member must have a primary interest in obtaining the best possible building for the school district at the lowest possible cost, rather than a business interest that can be served by the new construction. Money invested to pay a professional to serve this role will probably bring very much more return to the community than most dollars invested in consultants or visits to other schools.

It would be unfortunate if our suggestions were followed without careful consideration of local problems and local goals. And these goals will change over the life span of the building so maximum flexibility should be maintained. This flexibility should include movable interior walls and lab furniture. As we pointed out in Part 1, the design of science facilities cannot be considered without careful analysis of the type of relations between students and between students and staff that the community is ready and willing to accept. Our suggestions are based on the assumption that staff members, students, and the community as a whole want facilities and programs of the type that we believe are emerging if planning has been cooperative and extensive. We trust that this report will serve as a resource to school personnel and community personnel in self-appraisal of goals and directions. We hope that the recommendations contained in this chapter will lead to the design of science facilities and programs that better meet the needs of students at present and for at least the next quarter century. As more new facilities are designed and additional experience is acquired with types of facilities and programs suggested here, a new study will be called for. We hope that our efforts will have proved of value to the improvement of science instruction and to the quality of human experience that occurs in schools.

6.6 Space dividers and comfortable furniture can create excellent study areas within a science facility. Little Falls Central School.

6.7 With carpeted floors, students can discuss their work in almost any corner of the science facility.

Bibliography

Appendices

Part

3

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Annotated Bibliography

Ahl, David, and James Bailey. **Computers Are for Kids — Not for Geniuses.** *School Management* 15: 26-29, April 1971.

This article discusses the use of computers both in mathematics and other disciplines.

An Open Plan Encourages An Open Program. *School Management* 15: 12-14; August 1971.

The first "open space" high school in New York State was built at a cost of $17.15 per square foot, in Little Falls, New York. The article explains how the flexible physical structure encouraged the development of a more flexible program.

Brisby, William L. **A New Approach to Marine Biology on the High School Level.** *The American Biology Teacher* 30: 566-571; September 1968.

The Naval Missile Center at Point Mugu, California, in cooperation with Ventura College and the National Science Foundation, has been offering a marine science course for high school and junior college students who have high ability. Lectures are given one evening a week. Laboratory studies are held on Saturdays. The lab sessions "involve the participants in ecological studies of the Mugu Lagoon and the offshore islands, as well as visits to marine research institutions." The Missile Center maintains an up-to-date study center and laboratory facilities.

Brisby concludes the article by pointing out that "It is not solely the responsibility of educational institutions to train our superior students. This marine biology program was developed to allow for a cooperative utilization of military, industrial, and academic personnel and facilities . . ."

Calgan, Robert A. **Designing for Use.** *American School and University* 43: 38-40; May 1971.

This article contains very good suggestions for choosing furniture and building materials that will last. The author calls his concept "preventive maintenance."

Comparing School Air-Conditioning Systems. *American School and University* 42: 25-26; April 1970.

The article compares the advantages and disadvantages of three different air-conditioning systems: unit ventilators; rooftop units; and air units located in periphery space. No cost figures are given.

Corlett, William. **Flexibility in K-12 Schools.** *AIA Journal* 44: 59-62; November 1965.

Experience has proven that the initial cost of carpeting a school is more than offset by the reduced maintenance cost of floor surface and by the reduction in student falls. The author claims that student behavior is favorably affected by the carpeting.

Demountable partitions are the best way to provide potential flexibility. It costs about $100 to move a full-size partition.

Creager, Joan G., and Darrel L. Murray, editors. **The Use of Modules in College Biology Teaching.** The Commission on Undergraduate Education in the Biological Sciences, Washington, D.C. 1971.

Dawson, Richard G. **A Natural Science Camp for Pre-Teens.** *The American Biology Teacher* 29: 221-224; March 1967. The article centers on a resident camp area in Kansas City's Swope Park. The camp was designed for summer use by students completing grades 5-8. The article deals primarily with the kinds of projects that can be undertaken by students in such an area. Again, the emphasis is on program rather than facility.

Educational Facilities Laboratories. **Schools Without Walls.** Educational Facilities Laboratories, Inc., New York. 1965.

This article discusses acoustics problems encountered in an open-plan school and describes "what-to-do" and "what-not-to-do" for good acoustics. It emphasizes the problem of "acoustic deadness" when there is too much acoustic treatment in an area. The advantage of space around each group of students is also mentioned.

Educational Facilities Laboratories. **SCSD: The Project and the Schools.** Educational Facilities Laboratories, Inc., New York. 1967.

The School Construction Systems Development project in California studied methods for building better schools more rapidly and more economically. This booklet discusses those schools that have been built from the ideas developed during the project.

Flexibility is important. The article advocates demountable partitions, air-conditioning outlets, and flexible ducts which can be moved almost anywhere while attached to a five-foot grid. Lights are interchangeable with ceiling panels. There is a space between the roof deck and the ceiling which houses these facilities. Flexibility is also achieved through interchangeable cabinets and laboratory tables, with interchangeable drawers and shelving.

Some of the companies involved in this project were the following:

Lennox Industries (air conditioning)
E. F. Hauserman Co. (walls)
Hough Manufacturing Corporation (walls)
Educators Manufacturing Company (cabinets and laboratory stations)

Educational Facilities Laboratories. **Western Region Center. Study Carrels.** Educational Facilities Laboratories, Inc., New York. 1962.

Ten kinds of study carrels are described. Detailed drawings are included. No cost figures given.

A biology project carrel is described. It is a 6-booth unit containing a "Lazy Susan" for materials. Basic dimensions for carrels are given as follows:

- A carrel should be 2 feet deep and include a 6-square-foot working space.
- Dividers should be above eye level height (approximately 20 inches above the desk height).
- There should be 10-inch deep bookshelves.
- It should be possible for two students to sit at one carrel if necessary or desirable.

Provision should be made for utilities: a light, several 110-volt outlets, and special jacks for closed-circuit TV. The carrel should be designed to function either now or in the future, when new kinds of equipment might be installed. Optional features are also listed. Acoustical treatment for the carrel is suggested.

Electric Panels Heat a No-Wall School. *American School and University* 41: 37, 69; January 1969.

A middle school in Ohio used electric radiant heat panels in the ceiling in addition to the warmth generated by the students, staff, and lighting equipment, as the main source of heat for the school. For severe cold weather, supplementary heat from gas hot air blowers in the gymnasium is used for warmth.

Annotated Bibliography

Facts About Cooling It. *School Management* 15: 33; May 1971.

In Las Vegas, Nevada, an architectural firm designed different air-conditioning systems for "otherwise identical junior high schools." One system utilized chilled water from a single central water-cooled centrifugal chiller. An air-cooled unitary system was installed at the other school. It was found that the water-cooled system had certain advantages over the air-cooled. These advantages included a significant saving in electric power needed to run the system and the fact that "the cooling capacity of water-cooled refrigeration equipment does not tend to fall off at extremely high ambient temperatures. . . ."

Fall, Michael W. **Teaching Ecology in the Urban Environment.** *The American Biology Teacher* 31: 572-574; December 1969.

The emphasis here is on programs of study for outdoor classes in the urban environment, but the author also talks about certain gadgets that can be constructed to aid in such studies. For example, he has a section on the "Productivity of a Garbage Can," in which he explains how a garbage can could be covered with a screen trap for collecting flies.

Flansburgh, Earl R. **The Price of the Schoolhouse.** *Progressive Architecture* 53: 80-83; February 1972.

Greene, Kingsley L. **National Environment Awareness: Part I: Using Urban Resources.** *The American Biology Teacher* 29: 641-645; November 1967.

The article does not deal with facilities but describes how field trips can take place in the city and how interesting plant life can be found on a street corner.

Gupta, H. C. **How to Select a Mechanical System.** *Nation's Schools* 74: 58-59; October 1964.

This article describes five air-conditioning systems and gives criteria for selecting an air-conditioning system. An explanation is given with cost figures to show why thermal control is important. The author states that an increase in teaching efficiency of 4.3% is required to pay for air conditioning. He also claims that student learning goes up 25 to 30% in an air-conditioned room.

Hoover, Albert A. **Ceiling Systems Give Partitions a Push — in All Directions.** *Nation's Schools* 76: 70-71; November 1965.

This article describes a ceiling grid system which interlocks with movable partition systems. It is easily and quickly changed. Within the ceiling grid troughs are electric conduits, ducts for hot, cold, and return air, fluorescent light tubes, telephone lines, electric wiring raceways, switches, outlets, and low-voltage wiring for TV, radio, clocks, and an intercom system. Regardless of how the partitions are moved around, the grid elements can be adapted. This is slightly more expensive than conventional systems. Found in two elementary schools in Los Altos, California.

Hummer, Paul J. **The Outdoor Classroom — Forest, Stream, and Pond.** *The American Biology Teacher* 30: 177-180; March 1968.

This is a description of field activities carried out by BSCS Green Version biology students at Linganore Junior-Senior High School in Frederick, Maryland. The location for the field studies is Camp Greentop. The article provides outlines for student study of forest, pond, and stream. The emphasis here is on program, rather than facility, although it is made clear that the Camp Greentop area is particularly rich in certain biotic resources.

Instant Schools. *American School and University* 43: 36-40; June 1971.

The City of Chicago has begun to make use of small and odd-shaped plots of land by using "systems construction" for its schools. The buildings are designed in four-foot modules using two-foot increments and are built to last as long as conventionally constructed buildings. The date given for the completion of a school is usually 120 days after a site has been made available. Actual completion usually takes less time.

Each classroom has its own electric heating, ventilation, and air-conditioning system which can be controlled individually. "Almost all of the building components will not support combustion . . . and, since each room has its own heating and ventilation system, spread of fire, smoke, and other dangerous fire byproducts through the utility system is impossible. Over the first 20 years, maintenance cost should be only 50% of what they would be for a conventional building."

The Chicago schools are manufactured by Titan Environmental Construction Systems, Inc., and Kinetic Buildings, Inc. for a cost similar to or less than conventional schools.

Irving, James R. **How to Provide for Safety in the Science Laboratory.** National Science Teachers Association, Washington, D.C. 1968. 11 pp.

Jinks, Willard. **A Homemade Climatizing Unit for an Environmental Chamber.** *The American Biology Teacher* 32: 493-494; November 1970.

Johnston, Gordon S., Robert H. Ciullo, and Claude R. Gilmore. **Mobiolab 1: Nasson College.** *The American Biology Teacher* 31: 155-159; March 1969.

A good article on how a mobile field station was constructed in a war-surplus trailer. Design, utility, and equipment specifications are given, as is the cost of operation. (Field operations cost about $4.50 per day; transport to and from the site was about 32 cents per mile.)

Macbeth, Edwin W. **When the Walls Come Tumbling Down.** *School Management* 15: 8-11; August 1971.

This is a summary of the educational developments that led to the open-plan school design. It includes twelve suggestions for making the most of it. The suggestions which include those for design, lighting, acoustics, privacy requirements, spatial requirements, air conditioning, circulation patterns, furniture, carpeting, storage space, et cetera, would appear to be interesting and important to anyone planning an open-plan school.

The Metropolitan Toronto School Board Study of Educational Facilities. **SEF E3: Educational Specifications and User Requirements for Secondary Schools.** Ryerson Press, Toronto. 1970.

This is an ambitious study and plan. It begins where the Educational Facilities Laboratories *SCSD: The Project and the Schools* ended. It discusses the ultimate in an open system built of systems components constructed in 5 x 5-foot modules. Some building components from different manufacturers are used interchangeably. This leads to competitive bidding for production, since all manufacturers must meet the same criteria. Flexibility is the key word. Many examples and cost figures are given in the text. The study shows that this method of construction is more economical and that maintenance costs are less.

National Science Teachers Association. **Conditions for Good Science Teaching in Secondary Schools.** National Science Teachers Association, Washington, D.C. 1970.

Annotated Bibliography

New Shapes for New Sciences. *School Management* 12: 14-21; April 1968.

The article mentions special features of science areas in the following high schools: Martinsville, Virginia; South Shore High School, Chicago, Illinois; Aspen, Colorado; and Utica Junior High School, Utica, Michigan. These special features include student research carrels; movable, stackable lecture desks; a motor-operated demonstration platform; and mobile work stations. The article mentions features that are no longer desirable in science areas and tells why the plans of the above schools are an improvement. Negative features to be avoided are laboratories separate from lecture areas; overcrowding; inadequate storage; no preparation space for teacher use; and no provisions for more exotic sciences.

1971 Cost of Building Index. *School Management* 15: 12-31; June 1971.

Orlando F. Furno, Assistant Superintendent of the Baltimore City School District, developed this index. It gives detailed tables for the cost of building index, 1961-1971; for schools completed, 1965-1971; for increases in the cost of materials, on-site labor, and off-site labor, 1947-1971; and for trends in state and regional examination of dollars spent for public school building, 1969-1971.

Olfson, Lewy. **Building Codes: Something Needs to be Done.** *School Management* 14: 48-52; March 1970.

Olfson states that arbitrary codes make school plant innovation difficult and expensive. "Architects say codes must be revised to state objectives, rather than how objectives are to be achieved." Present codes often limit economy and efficiency of construction of facilities. The article emphasizes that school planners should employ construction code consultants and should anticipate conflicts with rigid codes.

On the Carpet. *Architectural and Engineering News* 7: October 1965.

Separate surveys were conducted by the American Carpet Institute and the Armstrong Cork Co. comparing the effectiveness and cost of carpeting versus resilient flooring. The results vary depending upon the source reporting.

Orgren, James. **An Outdoor School for Earth Science** *The Science Teacher* 33: 43-45; December 1966.
This article concerns a three-day program for eighth-graders at the Earth Science Outdoor School in Frederick County, Maryland. The area is used during the winter (the off-season) for the earth science program, which keeps the camp fees minimal. There is no real emphasis here on facilities, except for the idea of taking advantage of a camp such as this one during the off season.

Pasknik, Marion. **Factory Building to Modern School in Six Months.** *School Management* 15: 12-14, July 1971.

This is an interesting article about the conversion of a run-down Bronx factory building into a modern bilingual elementary school. The conversion was completed in six months at a cost of $15 per square foot in a city where the cost of building a new school runs about $50 per square foot. The author points out that the school is a carpeted, open-plan facility. He states that the fewer the walls, the lower the construction cost.

Pitluga, George. **Criteria for a Planetarium Presentation.** *The Science Teacher* 35: 51-52; December 1968.
The emphasis here is on the proper *use* of a facility rather than on the facility itself. It offers valid criticisms of the way in which planetariums are conventionally used, particularly in connection with lecture presentations.

Quakertown's Board Took a Long-Range Look and Built a Planetarium. *American School Board Journal* 156: 27-29; February 1969.

The planetarium built in the Quakertown (Pennsylvania) High School serves the entire community. It is used for astronomy, history, English, literature, mathematics, and physics. The cost was approximately $25,000 for basic equipment; $6-8,000 for the dome.

Rabb, George B. **Education and Zoos.** *The American Biology Teacher* 30: 291-296; April 1968.

The author, Associate Director of the Chicago Zoological Park in Brookfield, Illinois, explains how zoos can be better used for educational purposes. The emphasis is on more informative signs, tape recordings, etc.

Ruth, Ferdinand S. **Model Science Laboratories at the Lawrence Hall of Science.** *The Science Teacher* 36: 49-51; February 1969.

Ruth describes three model laboratory classrooms at Berkeley: biology, physics, and chemistry.

Biology: Special features here are a living wall containing tanks for fish and terrariums, exchangeable drawers in storage areas, two walls which have fiber-glass troughs, a back-lighted overhead projection on a frosted-glass screen, adjacent student research and study areas, and wet and dry preparation rooms.

Physics: Floor mosaic of electric outlets.

Chemistry: Floor utilities with flexible hose and electric cable for tables; portable chemical hoods.

Total Energy Makes This High School Independent. *American School and University* 41: 35, 68; January 1969.

Greater Muskegon Catholic Central High School uses a natural gas powered total-energy system. All of the power and light, most of the heat, and most of the air conditioning are furnished by this system. The article quotes substantial savings and claims that the cost is half of the average electricity cost (1.26 cents instead of 2.52 cents per kilowatt hour). There was a saving of $3,600 on power alone for the first six months.

Whitney, Robert Carey. **A Comprehensive Study of High School Physics Instructional Facilities.** Unpublished Thesis for Doctor of Philosophy, Cornell University. September 1963.

Based on questionnaire responses from science education experts and physics teachers as well as site visitations. Whitney concluded from this study that construction of physics facilities should (a) provide sufficient space and (b) allow for maximum flexibility in use.

Witt, James F. **Meteorology — Base for a Successful Activity Program.** *The Science Teacher* 34: 42-44; November 1967.

Witt relates how Lakeland High School in Shrub Oak, New York, developed its own weather station at minimal expense. The U.S. Weather Bureau donated surplus weather maps and two lighted drawing tables and granted the school station a license to receive circuit "A" information on a teletype machine rented from the American T & T Co. for $70 per month plus $1 per month/mile for a line charge. A private local weather service supplied the students' station with Circuit "C" teletype information.

Nomination Form

Form 70-2

NOMINATION FORM

A Study of Exemplary Facilities for Science Education in Secondary Schools

Conducted by the National Science Teachers Association
Supported by a grant from National Science Foundation

We consider the following facility appropriate for inclusion in the NSTA Study of Exemplary Facilities for Science Education in Secondary Schools:

Type of facility: We are searching for exemplary science facilities that would provide sufficient flexibility to meet present and future educational objectives. These facilities should make possible the inclusion or implementation of the following:

For the student

Instructional technology
Community resources
Library resources
Independent study areas
Duplication equipment
Carrel units
Project areas
Outdoor areas
Seminar and small group areas

For the science program

Differentiated staffing
Fused or integrated science
Natural areas
Seminars and small groups

In architectural features

Adequate space
Movable partitions
Flexible furniture
Traffic movement
Safety features
Good Lighting
Acoustical treatment
Storage

What makes the facility outstanding? Underline above criteria that apply and add any notes that would help us in selection.

Location (please give full address) ____________________

____

Person to contact for more information or arrangements to visit the facility:

Name ____________________ Position title ____________________

Address ____________________

____________________ Telephone: ____________________

Nomination submitted by: ____________________

Address ____________________

____________________ Telephone: ____________________

RETURN THIS FORM TO: Dr. Joseph D. Novak, Project Director
Division of Science Education, Stone Hall, Cornell University
Ithaca, New York 14850

List of Schools and Facilities Visited

Abington High School—North Campus
Abington, Pennsylvania

Academy of Glynn County
177 Yorktown Drive
Brunswick, Georgia

Adams Central High School
22 West Washington
Monroe, Indiana

Albion Junior High School
11109 Webster Road
Strongsville, Ohio

Aldo Leopold Elementary School
2602 Post Road
Madison, Wisconsin

Aloha High School
4855 S. W. Ericson
Beaverton, Oregon

Anniston High School
1301 Woodstock Avenue
Anniston, Alabama

Ashland Senior High School
Ashland, Oregon

Aspen High School
Aspen, Colorado

Athena High School
Rochester, New York

Auburn High School
Auburn, New York

Bedford Junior High School
Westport, Connecticut

Belmont High School
Belmont, Massachusetts

Bennington College
Department of Science
Bennington, Vermont

Boca Raton Junior High School
Northwest 8th Street
Boca Raton, Florida

Bowling Green Elementary School
Sacramento, California

Brattleboro Union High School
Brattleboro, Vermont

Brighton High School
2220 East 7600 South
Salt Lake City, Utah

Brockton High School
Brockton, Massachusetts

Brother Martin High School
4401 Elysian Fields Avenue
New Orleans, Louisiana

Burnt Hills-Ballston Lake Junior High School
Lake Hill Road
Burnt Hills, New York

Byram Hills High School
Armonk, New York

Canyon High School
19300 West Nadal Street
Saugus, California

Cary-Grove Community High School
Three Oaks Road and First Street
Cary, Illinois

Central Cabarrus High School
Route 5, Box 488
Concord, North Carolina

Charles A. Lindberg Senior High School
1001 Highway Seven
Hopkins, Minnesota

Clear Creek High School
Idaho Springs, Colorado

Cloverleaf Junior High School
7500 Buffham Road
Seville, Ohio

Coatesville Area Senior High School
Coatesville, Pennsylvania

Coleman Junior High School
1724 South Manhattan Street
Tampa, Florida

Concord High School
Alfred I. DuPont School District
2501 Ebright Road
Wilmington, Delaware

Connecticut Valley Regional High School
Peterborough, New Hampshire

Crestwood Elementary School
Manhattan Avenue
Tampa, Florida

Cubberly High School
4000 Middlefield Road
Palo Alto, California

Culver Military Academy
Culver, Indiana

List of Schools and Facilities Visited

Cupertino High School
P.O. Box F
Cupertino, California

Delaware Nature Education Center
P.O. Box 3900
Brandywine Creek State Park
Greenville, Delaware

Del Norte High School
5323 Montgomery, N. E.
Albuquerque, New Mexico

Dreher High School
701 Adger Road
Columbia, South Carolina

Earth-Space Science Education Center
140 Hurlburt Road
Fairport Central School
Fairport, New York

Enumclaw High School
Route 2, Box 610
Enumclaw, Washington

East Aurora High School
East Aurora, New York

Evanston Township High Schol
1600 Dodge Avenue
Evanston, Illinois

Falmouth Intermediate School
Oceanographic Education Center
Box 585
Falmouth, Massachusetts

Fitchburg State College
McKay Campus School
Fitchburg, Massachusetts

Fremont High School
P.O. Box F
Sunnyvale, California

George Washington High School
1005 Mount Vernon Avenue
Alexandria, Virginia

Glens Falls Junior High School
Glens Falls, New York

Governor Thomas Johnson High School
Frederick, Maryland

Greeley West High School
2401 35th Avenue
Greeley, Colorado

Greenwich Senior High School
Hillside Road
Greenwich, Connecticut

Gunn High School
780 Arastradero Road
Palo Alto, California

Hartsville High School
Clyburn Circle
Hartsville, South Carolina

Highland High School
8990 York Street
Thornton, Colorado

Highland Park High School
Topeka, Kansas

Highland Senior High School
9135 Erie Street
Highland, Indiana

Ho-Nee-Um Trail
Arbor Drive and Monroe Street
Madison, Wisconsin

Huffman High School
950 Springville Road
Birmingham, Alabama

Hughson Union High School
Hughson, California

Ithaca High School
Ithaca, New York

Jamesville-DeWitt Central School
Jamesville, New York

Jefferson Middle School
201 South Gammon Road
Madison, Wisconsin

John Adams High School
5700 N. E. 39th Avenue
Portland, Oregon

John Burroughs School
755 South Price Road
St. Louis, Missouri

John Jay High School
Fishkill, New York

John F. Kennedy Senior High School
Sacramento, California

Knox Junior High School
Park Road West
Salisbury, North Carolina

Lawrence Hall of Science
University of California Berkeley
Berkeley, California

L. E. Berger Middle School
West Fargo, North Dakota

Leto Comprehensive High School
Tampa, Florida

Lincoln Senior High School
Bloomington, Minnesota

Lindenhurst Junior High School
Lindenhurst, Long Island, New York

Little Falls Central School
Little Falls, New York

Los Alamos High School
Los Alamos, New Mexico

Los Gatos High School
High School Court
Los Gatos, California

Lowell Senior High School
2051 East Commercial Avenue
Lowell, Indiana

L. W. Higgins High School
1500 Berger Road
Marrero, Louisiana

Madison School Forest
Madison, Wisconsin

Madison Public Schools Planetarium
201 South Gammon Road
Madison, Wisconsin

Mahopac High School
Baldwin Place Road
Mahopac, New York

Maine Township High School North
9511 Harrison Street
Des Plaines, Illinois

Mansfield High School
Mansfield, Massachusetts

Marian Peterson High School
Santa Clara Unified School District
Santa Clara, California

Mariemont High School
3812 Pocohontas Avenue
Cincinnati, Ohio

Marple-Newtown Senior High School
120 Media Line Road
Newtown Square, Pennsylvania

Marshall High School
401 South Saratoga
Marshall, Minnesota

Mascenic Regional School
New Ipswich, New Hampshire

Mattacheese Middle School
Higgins-Crowell Road
West Yarmouth, Massachusetts

McGavock High School
McGavock Pike
Donelson, Tennessee

McLean High School
McLean, Virginia

Medford High School
Medford, Massachusetts

Meramac Community College
959 South Geyer Road
St. Louis, Missouri

Mid-continent Regional Education Laboratory
104 East Independence Avenue
Kansas City, Missouri

Midvale Junior High School
138 Pioneer Street
Midvale, Utah

Mill Hollow Environmental Center
Granite School District
Mill Hollow, Utah

Monadnock Regional High School
Swanzey, New Hampshire

Monona Grove High School
4400 Monona Drive
Monona, Wisconsin

Mt. Greylock Regional High School
Cold Spring Road—Route Number 7
Williamstown, Massachusetts

Mt. Lebanon High School
Cochran Road
Pittsburgh, Pennsylvania

Munster High School
8808 Columbia Avenue
Munster, Indiana

List of Schools and Facilities Visited

Nashville Science Center
12 and Edgehill
Nashville, Tennessee

Nathaniel H. Wixon Middle School
Dennis, Massachusetts

"Nature's Classroom"
Instructional Services Center
707 East Columbus Drive
Tampa, Florida

New Trier High School West
Northfield, Illinois

Niskayuna Senior High School
1626 Balltown Road
Schenectady, New York

Northeast High School
Project SPARC
Cottman and Algon Avenues
Philadelphia, Pennsylvania

North Kirkwood Junior High School
11311 Manchester Road
Kirkwood, Missouri

Nova High School
3600 S. W. College Avenue
Ft. Lauderdale, Florida

Oak Grove High School
285 Blossom Hill Road
San Jose, California

Oak Grove Junior High School
Bloomington, Minnesota

Pasadena High School
206 South Shaver
Pasadena, Texas

Phillips Academy
Andover, Massachusetts

Pinecrest High School
Southern Pines, North Carolina

Plymouth Junior High School
1011 36th Avenue, North
Robbinsdale, Minnesota

Project ES—70 School
Philadelphia, Pennsylvania

Randolph High School
Memorial Drive
Randolph, Massachusetts

Rolling Meadows High School
Arlington Heights High School District 214
Arlington Heights, Illinois

Roy High School
Roy, Utah

St. Andrews Presbyterian College
Laurinburg, North Carolina

Salem High School
Salem, New Hampshire

Sam Rayburn High School
2121 Cherrybrooke Lane
Pasadena, Texas

San Clemente High School
700 Avenido Pico
San Clemente, California

Sand Ridge Junior High School
Roy, Utah

Science Resource Center
8846 Westview
Houston, Texas

Shawnee Mission East High School
Shawnee Mission, Kansas

Shawnee Mission Northwest High School
67th and Quivera Road
Shawnee Mission, Kansas

Shawnee Mission South High School
5800 West 107th Street
Shawnee Mission, Kansas

Somerset High School
Somerset, Massachusetts

Somersworth Middle School
Somersworth, New Hampshire

Southeastern Pennsylvania Outdoor
Education Center
Sycamore Mills Road
Media, Pennsylvania

South Glens Falls Central School
South Glens Falls, New York

South Weymouth High School
South Weymouth, Massachusetts

Space Science Laboratory
Middletown Public Schools
Middletown, Rhode Island

Sperry High School
1977 Lehigh Station Road
Henrietta, New York

Stoughton High School
Stoughton, Massachusetts

Taconic High School
Pittsfield, Massachusetts

The Wheatley School
Old Westbury, New York

Thomas Jefferson Senior High School
Bloomington, Minnesota

Ticonderoga Elementary and Middle School
Ticonderoga, New York

Trumbell Junior High School
Trumbell, Connecticut

University High School
Hunting Valley, Ohio

Virgil Grissom High School
7901 Bailey Cove
Huntsville, Alabama

Vista Middleschool
Ferndale, Washington

Wayland Academy
Beaver Dam, Wisconsin

Webster Groves High School
100 Selma Avenue
Webster Groves, Missouri

Williamsville Central School
Williamsville, New York

William W. Mitchell High School
1205 Potter Drive
Colorado Springs, Colorado

Wilson Laboratory School
Mankato State College
Mankato, Minnesota

Wilton High School
Wilton, New Hampshire

Woodway Senior High School
23200 100th West
Edmonds, Washington

Correspondence Only

Concord-Carlisle High School
Concord, Massachusetts

Fort Benton High School
Fort Benton, Montana

Longmeadow Middle School
Longmeadow, Massachusetts

Plantation Middle School
Plantation, Florida

Senior High School
Lisbon Falls, Maine

Stanislaus State College
800 Monte Vista Avenue
Turlock, California

Listing by Regions and States

Northeast

Connecticut
Bedford Junior High School
Greenwich Senior High School
Trumbell Junior High School

Massachusetts
Belmont High School
Brockton High School
Falmouth Intermediate School
Fitchburg State College
Mansfield High School
Mattacheese Middle School
Medford High School
Mt. Greylock Regional High School
Nathaniel H. Wixon Middle School
Phillips Academy
Randolph High School
Somerset High School
South Weymouth High School
Stoughton High School
Taconic High School

New Hampshire
Connecticut Valley Regional High School
Mascenic Regional School
Monadnock Regional High School
Salem High School
Somersworth Middle School
Wilton High School

New York
Athena High School
Auburn High School
Burnt Hills-Ballston Lake Junior High School
Byram Hills High School
Earth-Space Science Education Center
East Aurora High School
Glens Falls Junior High School
Ithaca High School
Jamesville-DeWitt Central School
John Jay High School
Lindenhurst Junior High School
Little Falls Central School
Mahopac High School
Niskayuna Senior High School
South Glens Falls Central School
Sperry High School
The Wheatley School
Ticonderoga Elementary and Middle School
Williamsville Central School System

Rhode Island
Space Science Laboratory

Vermont
Bennington College
Brattleboro Union High School

Middle Atlantic

Delaware
Concord High School
Delaware Nature Education Center

Maryland
Governor Thomas Johnson High School

Ohio
Albion Junior High School
Cloverleaf Junior High School
Mariemont High School
University High School

Pennsylvania
Abington High School—North Campus
Coatesville Area Senior High School
Marple-Newtown Senior High School
Mt. Lebanon High School
Northeast High School
Project ES—70 School
Southeastern Pennsylvania Outdoor Education Center

Southeast

Alabama
Anniston High School
Huffman High School
Virgil Grissom High School

Florida
Boca Raton Junior High School
Coleman Junior High School
Crestwood Elementary School
Leto Comprehensive High School
"Nature's Classroom"
Nova High School

Georgia
Academy of Glynn County

North Carolina
Central Cabarrus High School
Knox Junior High School
Pinecrest High School
St. Andrews Presbyterian College

South Carolina
Dreher High School
Hartsville High School

Virginia
McLean High School
George Washington High School

Upper Midwest

Illinois
Cary-Grove Community High School
Evanston Township High School
Maine Township High School North
New Trier High School West
Rolling Meadows High School

Indiana
Adams Central High School
Culver Military Academy
Highland Senior High School
Lowell Senior High School
Munster High School

Minnesota
Charles A. Lindberg Senior High School
Lincoln Senior High School
Marshall High School
Oak Grove Junior High School
Plymouth Junior High School
Thomas Jefferson Senior High School
Wilson Laboratory School

Missouri
John Burroughs School
Meramac Community College
Mid-continent Regional Education Laboratory
North Kirkwood Junior High School
Webster Groves High School

North Dakota
L. E. Berger Middle School

Tennessee
McGavock High School
Nashville Science Center

Wisconsin
Aldo Leopold Elementary School
Ho-Nee-Um Trail
Jefferson Middle School
Madison Public Schools Planetarium
Madison School Forest
Monona Grove High School
Wayland Academy

South Central

Colorado
Aspen High School
Clear Creek High School
Greeley West High School
Highland High School
William W. Mitchell High School

Kansas
Highland Park High School
Shawnee Mission East High School
Shawnee Mission Northwest High School
Shawnee Mission South High School

Louisiana
Brother Martin High School
L. W. Higgins High School

New Mexico
Del Norte High School
Los Alamos High School

Texas
Pasadena High School
Sam Rayburn High School
Science Resource Center

Utah
Brighton High School
Midvale Junior High School
Mill Hollow Environmental Center
Roy High School
Sand Ridge Junior High School

West

California
Bowling Green Elementary School
Canyon High School
Cubberly High School
Cupertino High School
Fremont High School
Gunn High School
Hughson Union High School
John F. Kennedy Senior High School
Lawrence Hall of Science
Los Gatos High School
Marian Peterson High School
Oak Grove High School
San Clemente High School

Oregon
Aloha High School
Ashland Senior High School
John Adams High School

Washington
Enumclaw High School
Vista Middleschool
Woodway Senior High School

Environmental Criteria

Reproduced with permission from The Metropolitan School Board Study of Educational Facilities. *SEF E3 Educational Specifications and User Requirements for Secondary Schools*. Toronto, Canada. 1970.

Level	Square Feet	Area
Secondary	7275	Laboratories – general science, physics, chemistry, etc.

Environmental Criteria

Atmospheric Criteria		Desirable	Tolerance	Remarks
Temperature	outside temperature >90 F°	75°-78°	±2°	(See Appendix)
	outside temperature < 0 F°	72°-75°	±2°	
Relative Humidity	outside temperature >90 F°	45%-55%	±5%	
	outside temperature < 0 F°	25%-30%	±5%	
Outside Air *	CFM per sq ft	0.5-0.8	>0.3	*Exhaust requirements will govern
	CFM per person	15-30	>10	
Air Changes *	per hour	10-12	>8	
Air Movement	velocity: FPM	25-40	±10	
Room Pressure	in. WG	−0.10	< −0.05	
Air Filter Efficiency	>5μ	80%	—	
	<4μ	45%-80%	—	
Odors Body, Chemical, Animal				
Population	max 200	min		
Heat Gain	source	watts	BTUH	
	Lighting	2-4/sq ft		
	AV equipment	Varies		
	Experiments	Varies	Varies	

Visual Criteria

Visual Performance Index (VPI) 63.0			Ft Candles N/A
View Out Op'l	View In No	Blackout Yes	Privacy No
Daylight Op'l	Level Control Yes		

Acoustic Criteria

Ambient Noise Level: NC 35 max

							Remarks
Reverberation Time (in seconds)	Frequency: cps	125	250	500	1000	2000	
	max			N/A			Reverberation time calculation not meaningful
	min			N/A			
Generated Noise Level (in db re .0002 dynes/cm²)	Frequency: cps	31.5	125	500	2000	8000	
	design level			77			

Services

Mechanical Services				Remarks
CW Yes	HW Yes	Steam No	Gas Yes	Master control valves for gas and water
Air No	Drain Yes	Exhaust *		*Fume hoods and canopies
Other				

Electrical Services

PA Yes	Intercom Yes	Handset Yes	Bell Tel No
Program System Yes		Clock System Yes	TV Terminal Yes
Computer Terminal No		Underfloor Duct System No	
Power 120V – 1ϕ for AV and student experiments			
Other			

Notes

In the consideration of nuisance smells and odors in atmospheric comfort framework, the duration of the experiments and the number of malodorous experiments could have a direct bearing upon the economics of providing extensive ventilating systems. If the intent is to provide a flushing action only, to prevent a short-term experiment – using, for instance, hydrogen sulphate – from affecting all of the surrounding areas, this can be accommodated in various ways.

The location of the laboratory, its air-tightness in relation to other spaces, its location and proximity to outside wall could have a bearing upon the design.

A soft floor finish is desirable for acoustical reasons and to prevent breakage of fragile equipment.

Level	Square Feet	Area
Secondary	895	Storage-Preparation Area – Science

Environmental Criteria

Atmospheric Criteria			Desirable	Tolerance	Remarks
Temperature	outside temperature	>90 F°	75°-78°	±2°	
		< 0 F°	72°-75°	±2°	
Relative Humidity	outside temperature	>90 F°	45%-55%	±5%	
		< 0 F°	25%-30%	±5%	
Outside Air *		CFM per sq ft	0.3-0.8	>0.15	*Exhaust requirements will govern
		CFM per person	15-30	>8	
Air Changes *		per hour	8-10	>6	
Air Movement		velocity: FPM	25-40	±10	
Room Pressure		in. WG	−0.10	< −0.05	
Air Filter Efficiency		$>5\mu$	80%	—	
		$<4\mu$	45%-80%	—	
Odors Body, Chemical					
Population	max 12		min		
Heat Gain	source		watts	BTUH	
	Lighting		2-4/sq ft		
	Equipment		Varies	Varies	

Visual Criteria

Visual Performance Index (VPI) 63.0 Ft Candles N/A

View Out Op'l View In Op'l Blackout Yes Privacy No

Daylight Op'l Level Control Yes

Acoustic Criteria

Ambient Noise Level: NC 35

Reverberation Time (in seconds)	Frequency: cps	125	250	500	1000	2000
	max			1.0		
	min			—		
Generated Noise Level (in db re .0002 dynes/cm^2)	Frequency: cps	31.5	125	500	2000	8000
	design level			Varies		

Services

Mechanical Services				Remarks
CW Yes	HW Yes	Steam No	Gas Yes	Master valve for gas
Air No	Drain Yes	Exhaust Fume hood		
Other				

Electrical Services

PA Yes Intercom Yes Handset Yes Bell Tel No

Program System No Clock System Yes TV Terminal No

Computer Terminal No Underfloor Duct System No

Power 120V – 1ϕ for instrument and tool use

Other 208V – 1ϕ for range outlet if used

Notes

Environmental Criteria

Level	Square Feet	Area
Secondary	750	Resource area – Science

Environmental Criteria

Atmospheric Criteria			Desirable	Tolerance	Remarks
Temperature	outside temperature	>90 F°	75°-78°	±2°	
		< 0 F°	72°-75°	±2°	
Relative Humidity	outside temperature	>90 F°	45%-55%	±5%	
		< 0 F°	25%-30%	±5%	
Outside Air		CFM per sq ft	0.3-0.8	>0.15	
		CFM per person	15-30	>10	
Air Changes		per hour	8-10	>6	
Air Movement		velocity: FPM	25-40	±10	
Room Pressure		in. WG	+0.10	> +0.05	
Air Filter Efficiency		>5μ	80%	—	
		<4μ	45%-80%	—	
Odors Body					
Population	max 25		min		
Heat Gain	source		watts	BTUH	
	Lighting		2-4/sq ft		
	AV equipment		Varies		

Visual Criteria

Visual Performance Index (VPI) 63.0 Ft Candles N/A

View Out Op'l View In No Blackout Yes Privacy No

Daylight Op'l Level Control Yes

Acoustic Criteria

Ambient Noise Level: NC 35 max

							Remarks
Reverberation Time (in seconds)	Frequency: cps	125	250	500	1000	2000	Acoustical treatment of floor and ceiling is recommended
	max			1.0			
	min			0.5			
Generated Noise Level (in db re .0002 dynes/cm^2)	Frequency: cps	31.5	125	500	2000	8000	
	design level			77			

Services

Mechanical Services Remarks

CW No HW No Steam No Gas No

Air No Drain No Exhaust No

Other

Electrical Services

PA Yes Intercom Yes Handset Yes Bell Tel No

Program System Yes Clock System Yes TV Terminal Yes

Computer Terminal Op'l Underfloor Duct System No

Power

Other

Notes

Level	Square Feet	Area
Secondary	480	Growing room – Science

Environmental Criteria

Atmospheric Criteria			Desirable	Tolerance	Remarks
Temperature	outside temperature	>90 F°	70°-78°	±2°	
		< 0 F°	70°-78°	±2°	
Relative Humidity	outside temperature	>90 F°	60%-70%	±5%	40% min
		< 0 F°	60%-70%	±5%	
Outside Air	CFM per sq ft		0.5-0.8	>0.3	
	CFM per person		15-30	>10	
Air Changes	per hour		10-12	>8	
Air Movement	velocity: FPM		25-40	±10	
Room Pressure	in. WG		−0.15	< −0.10	
Air Filter Efficiency		>5μ	80%	—	
		<4μ	45%-80%	—	
Odors	Body, chemicals, animal, plant				
Population	max 20		min		
Heat Gain	source		watts	BTUH	
	Lighting		2-4/sq ft		
	Experiments		Varies	Varies	

Visual Criteria

Visual Performance Index (VPI) N/A — Ft Candles 70

View Out Yes — View In Op'l — Blackout Yes — Privacy No

Daylight Yes — Level Control Yes

Acoustic Criteria

Ambient Noise Level: NC 35

Reverberation Time (in seconds)	Frequency: cps	125	250	500	1000	2000
	max			1.0		
	min			—		
Generated Noise Level (in db re .0002 dynes/cm^2)	Frequency: cps	31.5	125	500	2000	8000
	design level			Varies		

Services

Mechanical Services — Remarks

CW Yes	HW Yes	Steam No	Gas No
Air Yes	Drain Yes	Exhaust	
Other			

Electrical Services

PA Yes	Intercom Yes	Handset Yes	Bell Tel No
Program System Yes		Clock System Yes	TV Terminal No
Computer Terminal No		Underfloor Duct System No	

Power 120V – 1ϕ for timers, special lighting, and experiments

Other

Notes

Sufficient circuits and timing controls should be provided for high concentration of growth lighting fixtures.